

DESCRIPTION AND IDENTIFICATION
OF LARVAL FISHES IN ALASKAN FRESHWATERS

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DESCRIPTION AND IDENTIFICATION
OF LARVAL FISHES IN ALASKAN FRESHWATERS

A
THESIS

Presented to the Faculty of the University of Alaska
in Partial Fulfillment of the Requirements
for the Degree of

MASTER OF SCIENCE

By

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Fairbanks, Alaska

May, 1988

ABSTRACT

Identification of larval fish is important for assessing fish populations and human impact on fish ecosystems but is difficult due to subtle differences between larvae of different species. A key to larval fishes is valuable for successful population studies. This thesis is a preliminary study towards the development of a key to the larval stages of Alaskan freshwater fishes. Early life history information on 23 of approximately 40 Alaskan freshwater species was obtained from the literature. Six of these species (sheefish, Stenodus leucichthys; Arctic grayling, Thymallus arcticus; Arctic char, Salvelinus alpinus; Dolly Varden, S. malma; longnose sucker, Catostomus catostomus; and slimy sculpin, Cottus cognatus) were laboratory-reared or collected near Fairbanks for additional information. Technical illustrations and morphometric data were prepared for each of the six species. This study indicates that follow-up research on several whitefishes will be critical for developing a comprehensive larval fish key to Alaskan freshwater species.

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ACKNOWLEDGEMENTS

The Sportfish Division of the Alaska Department of Fish and Game (ADFG) provided the financial support for this project. My committee chairman, Dr. James B. Reynolds, inspired me to incorporate my skill as an illustrator with my training as a biologist by suggesting this project; I thank him for that. Drs. Ronald L. Smith and Willard E. Barber made up the rest of my advisory committee and contributed much needed helpful advice. Helping with egg and larvae collections were students and technicians with the Alaska Cooperative Fishery Research Unit (ACFRU): Paul Skvorc, Bob Clark, Don Martin, Saree Gregory, Jason Offerman and Mike Jackson. ACFRU students Kate Wedemeyer and Nicholas Hughes also aided in egg and larvae collections, but their continuing encouragement and friendship were even more appreciated. Without the help of ADFG personnel at Clear Hatchery, I would not have been able to have such an excellent series of Arctic char, Arctic grayling, and sheefish specimens to illustrate. I thank Dave Parks, the hatchery manager, and Don Bee and Tim Burke for providing me with such fine specimens. Ken Alt, biologist with the Sportfish Division of the Alaska Department of Fish and Game, contributed his time and knowledge towards the whitefish section of this thesis. Rae Baxter loaned me

sixteen years of invaluable data and expertise on several species of freshwater fishes from western Alaska. Darryl Snyder and Robert Muth of the Larval Fish Laboratory in Fort Collins, Colorado gave me invaluable direction on all aspects of gathering information on larval stages. Their love of fish early life history certainly rubbed off on me. Bente Everheart and Susan Sarabasha, Directors of the Guild of Natural Science Illustrators Summer Workshop, helped expand my knowledge and skill in various illustration techniques. Lastly, two very special people made the completion of this thesis possible. My daughter, Rachael Skye, born in the midst of this project, gave me an intimate insight into early life history and the desire to complete the project so we could get on with life. Finally, my husband, Matthew, provided the loving guidance, encouragement, continual confidence in my abilities, and the not-always-gentle nudging to help me complete this thesis. To him I am especially grateful.

INTRODUCTION

Purpose

Early life stages of fish are fragile, highly sensitive to environmental changes, and especially susceptible to the impact of human activities. Adverse impacts on specific fish populations and entire ecosystems sometimes can be detected first by a decline in the numbers or health of larval fish. Increased knowledge of fish ontogeny also aids in more effective management of fishery resources. For these reasons it is important to study the early life history of fishes.

It is difficult to identify larval fishes because of their similarity in structure and form at the generic level. It is especially difficult to identify larval fishes without a key. Gross morphological differences during the larval period lead to the necessity of two keys: one for stages prior to fin ray differentiation and another when principal fin ray differentiation is complete. No keys presently exist for any of the larval stages of freshwater fishes of Alaska. The purpose of this thesis is to provide groundwork for such keys.

To provide a substantial base for dichotomous keys of larval stages of Alaskan freshwater fishes, I chose to

concentrate on 23 of the approximately 40 species which spawn in Alaskan freshwaters. Because the commercially important salmonids are well studied and have adequate descriptions of the larval stages, they were excluded. For all 23 species (Table 1), I obtained information on the early life history, including information on general distribution and ecology, spawning habitat and season, and descriptions of the early development where available. In addition, I collected and studied the larval phases of six of these species which were chosen because little information has been gathered on their early life histories; there were few or no illustrations; and they were readily available at Clear Hatchery (Alaska Department of Fish and Game) or in nearby river systems. These six species were: Arctic char, Salvelinus alpinus; Dolly Varden, Salvelinus malma; Arctic grayling, Thymallus arcticus; sheefish, Stenodus leucichthys; longnose sucker, Catostomus catostomus; and slimy sculpin, Cottus cognatus. For each of these species, original, detailed drawings of the early life stages were prepared. Morphometric and meristic data were also collected. An appendix containing the original morphometric data is on file in the office of the Alaska Cooperative Fishery Research Unit (ACFRU) on the University of Alaska Fairbanks (UAF) campus.

This preliminary work has indicated that keys for both

Table 1. Scientific and common names of Alaskan freshwater fishes included in this study.

Scientific Name	Common Name
<u>Stenodus leucichthys</u> (Guldenstadt)	sheefish
<u>Coregonus sardinella</u> Valenciennes	least cisco
<u>C. laurettae</u> Bean	Bering cisco
<u>C. autumnalis</u> (Pallas)	Arctic cisco
<u>Prosopium coulteri</u> (Eigenmann and Eigenmann)	pygmy whitefish
<u>P. cylindraceum</u> (Pallas)	round whitefish
<u>Coregonus nasus</u> (Pallas)	broad whitefish
<u>C. clupeaformis</u> complex	
<u>C. nelsoni</u> Bean	Alaska whitefish
<u>C. pidschian</u> (Gmelin)	humpback whitefish
<u>C. clupeaformis</u> (Mitchill)	lake whitefish
<u>Salvelinus alpinus</u> (Linnaeus)	Arctic char
<u>S. malma</u> (Walbaum)	Dolly Varden
<u>Thymallus arcticus</u> (Pallas)	Arctic grayling
<u>Hypomesus olidus</u> (Pallas)	pond smelt
<u>Dallia pectoralis</u> Bean	Alaska blackfish
<u>Couesius plumbeus</u> (Agassiz)	lake chub
<u>Catostomus catostomus</u> (Forster)	longnose sucker
<u>Percopsis omiscomaycus</u> (Walbaum)	trout-perch
<u>Lota lota</u> (Linnaeus)	burbot
<u>Pungitius pungitius</u> (Linnaeus)	ninespine stickleback
<u>Cottus cognatus</u> Richardson	slimy sculpin
<u>C. asper</u> Richardson	prickly sculpin
<u>C. aleuticus</u> Gilbert	coastrange sculpin

these stages will require, at a minimum, additional specific study on the early life history of the family Coregonidae. Specific recommendations appear at the end of this thesis.

Terminology

The following descriptive terms relating to early life history of fishes have been used in the text. Some of the terminology is illustrated (Figure 1).

Actinotrichia - horny fin supports which are the precursors of the fin rays or spines (lepidotrichia).

Axillary process - a triangular scalelike projection lying at the base of the pelvic fin.

Caudal peduncle - the fleshy end of the body behind the anal fin and before the caudal or tail fin.

Chromatophore - cell which contains pigments and is located mainly in the dermis of the skin. Usually appears as a central dot with radial branches. Melanophores are chromatophores whose pigments are mainly dark red, brown, or black.

Epaxial - the portion of the body above the horizontal myoseptum.

Finfold - see median finfold and preanal finfold.

Hypaxial - the portion of the body below the horizontal myoseptum.

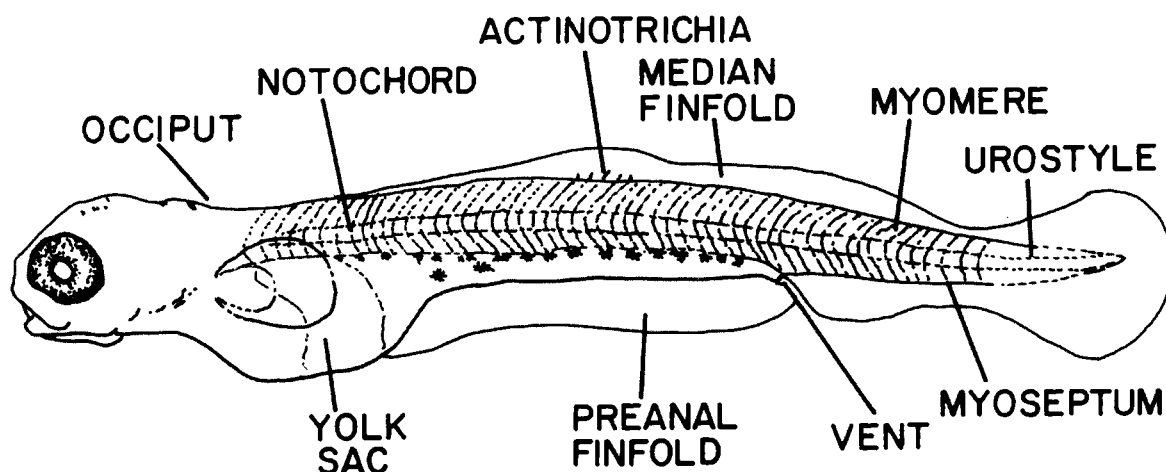
Hypural plate - the bony structure that supports the caudal fin rays in most teleost fishes.

Insertion (of a fin) - the posterior portion of the fin base, that is, the part of the fin base farthest from the head.

Juvenile period - the period of time during which the fish has attained the adult complement of spines and rays and the finfold has been completely absorbed (Snyder 1976).

Larval period - the time between hatching and the juvenile

A. PROTOLARVA



B. METALARVA

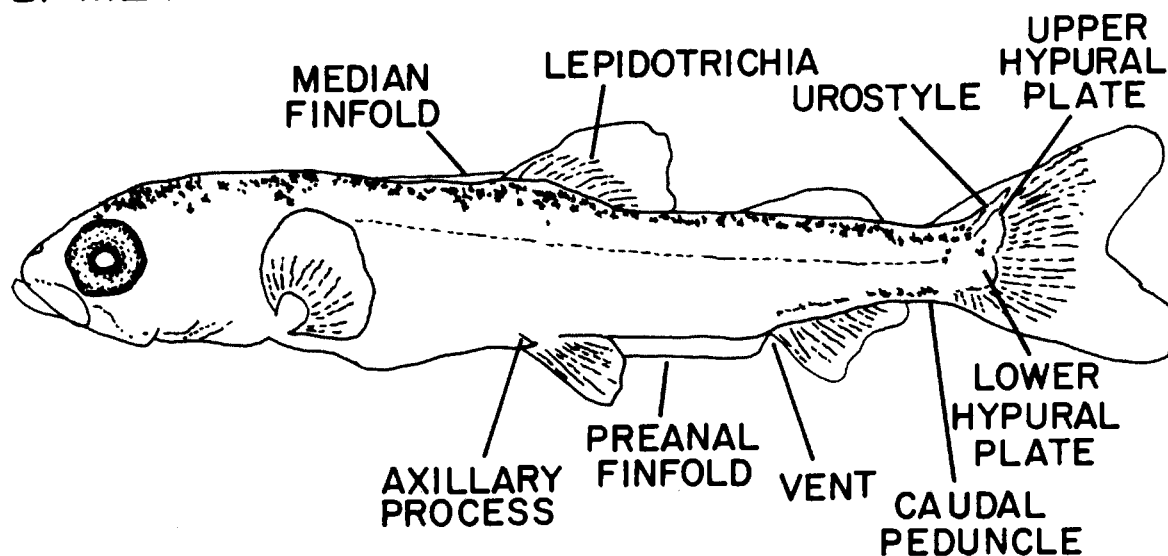


Figure 1. Idealized larvae illustrating basic anatomical features which have been referred to in this study.

period. The larval period consists of three phases: the protolarval phase, the mesolarval phase, and the metalarval phase (Snyder 1976).

Lepidotrichia - replacements of actinotrichia; soft fin rays or spines.

Median finfold - precursor to the median fins. It usually originates on the dorsal surface anterior to the occiput and extends down to the middle of the back, around the tail and forward to the vent.

Median fins - the dorsal, caudal, and anal fins.

Melanophores - chromatophores whose pigments are mainly dark red, brown, or black. Stellate melanophores are those which have a central dot with radial branches. Contracted melanophores are those which appear to be just a dark dot.

Meristics - counts of serial anatomical features such as myomeres, vertebrae, or gill rakers.

Mesolarval phase - the phase characterized by the appearance of at least one distinct principal ray in any of the median fins (Snyder 1976).

Metalarval phase - the phase characterized by the development of the full adult complement of principal rays in the median fins (Snyder 1976).

Morphometry - the measurement of the external form of the fish.

Myomere - repeated segments of muscle tissue of which there are approximately the same number as vertebrae.

Myoseptum - connective tissue found between adjacent myomeres.

Occiput - nape; the part of the body immediately behind the head on the dorsal surface.

Notochord - the embryonic cartilaginous vertebral column.

Nuptial tubercles - small projections that occur on the head, the body, or the lower fins of males and less often on females of some species during the breeding season.

Origin (of a fin) - the anterior end of the fin base; the end of the fin base nearest the head.

Peritoneum - membraneous lining of the abdominal cavity.

Preal anal finfold - that part of the finfold which originates at the yolk sac and extends posteriorly to the vent.

Preal anal myomeres - the number of myomeres from the nape to an imaginary vertical line at the most posterior point of the anus, including any myomeres bisected by the line.

Protolarval phase - the phase characterized by the absence of distinct spines or rays associated with median fins (caudal, dorsal, and anal fins) (Snyder 1976).

Pterygiophore - bone of the internal skeleton supporting the dorsal and anal fins.

Redd - the gravel nest of salmonid fishes.

Squamation - covering of scales.

Standard length (SL) - distance from the most anterior point on the snout to the most posterior point of the notochord or hypural complex.

Total length (TL) - distance from the most anterior point on the snout to the most posterior point on the caudal fin or finfold.

Urostyle - the last vertebral segment. It is usually modified (pointed) and reduced.

METHODS

For the 23 species discussed in this thesis, data on early life history were collected from available references and used to write descriptions. Six of these 23 species were raised from eggs or collected and used for producing original illustrations and morphometric data. For illustrations, collections of larvae were made as often as possible in order to obtain a good series of specimens of early developmental phases. Optimally, I planned to collect 6-12 specimens every 2-3 days or, for the slower-growing species, at least weekly. In the end, the number of specimens collected from those I raised in the laboratory depended on the number of eggs that successfully hatched and the survival rate of the larvae. Due to low hatch rates and poor survival, my collections provided only the minimal amount of material needed for illustrating and describing the early life phases. I supplemented these collections with wild caught larvae where possible.

All specimens were fixed in a 10% formalin solution, then transferred to a 5% phosphate-buffered formalin (Snyder 1983). Specimens were stored in 20 ml Kimble Disposable Scintillation vials and labeled inside and out with the critical data concerning the species type and method of collection. The specimens are now on deposit in the Aquatic

Collection, University of Alaska Fairbanks (UAF) Museum.

Specimen Collections

Arctic Char and Arctic Grayling

Arctic char and Arctic grayling eggs were reared at Clear Hatchery, located on the Clear Air Force Station 130 km southwest of Fairbanks on the Parks Highway. Arctic char eggs were obtained in 1985 from Amiloyak Lake in the Brooks Range by the live-spawning method. The rearing temperature was 4.1°C. Arctic grayling eggs were collected from Moose Lake, near Glennallen, also by the live-spawning method. The initial rearing temperature, 4.0°C, was gradually warmed to 13.5°C. Specimens representative of the developmental stages of these fishes were collected bimonthly and preserved by hatchery personnel.

Sheefish

Sheefish were also raised by Clear Hatchery. In 1986, hatchery personnel were unable, however, to take as many samples as I felt necessary to obtain a complete collection of the earliest developmental stages. I, therefore, raised sheefish in the laboratory at UAF using eggs obtained in September 1985 by the live-spawning method from hatchery stock. These were incubated at 3.8°C at Clear Hatchery until the eyed stage at which time they were transported to University facilities. Eggs were placed in an Instant Ocean

Aquarium in tap water which was circulated through an Aquaclear 2000 Filter and a Model XL Diatom Filter. Because of the accumulation of nitrogenous wastes, it was necessary to change the water every few days. Hatching began on 11 February, and larvae were fed ground tropical fish food and live brine shrimp. After the first week of intensive hatching, the water temperature was raised slowly to a maximum of 11.0°C over a 60 day period.

Rearing appeared to be successful until 6 March, when some larvae were observed drifting motionless to the bottom of the tank, then swimming rapidly towards the surface before sinking back to the bottom, a behavior which was repeated until the larvae died. The cause may have been starvation as the fish were fed only on the weekdays at four hour intervals between 0800 and 1700. Two automatic feeders were then purchased and placed on the tank. The combined feeders allowed feeding every six hours during times when they could not be hand fed. Also, Vortex Superchar powdered activated carbon was added to the diatom filter to aid in clearing up the water which tended to get cloudy two to three days after changing the water.

By 14 April 1986, however, the last of the larvae perished due partially to filter malfunction. Until this time, collections had been made every 2-3 days for the first month then weekly thereafter providing a good series of the

earliest developmental stages.

In 1987, Clear Hatchery was able to provide a full developmental series of sheefish from the 1987 stock. The eggs were obtained from Koyukuk River stock by the live-spawning method. These specimens appeared healthier than the ones I raised and have been used for morphometric measurements and illustrations.

Longnose Sucker

Longnose sucker eggs and milt were collected from suckers in Badger Slough near Fairbanks on 26 May 1985. The eggs were placed in a container and layered with gravel. The container was placed under the outflow of a Aquaclear 2000 filter in an Instant Ocean Aquarium, allowing exchange of fresh water and nitrogenous wastes. Eggs hatched in 7 days at 17.0°C, the temperature of Badger Slough where the spawning adults were collected. Rearing continued through July with specimens collected weekly until the end of July when all specimens had been preserved. Because the last larvae preserved were only in the early metalarval phase, trips were made to Badger Slough in both 1985 and 1986 to collect metalarvae and juveniles.

Slimy Sculpin

Fertilized slimy sculpin eggs were obtained from beneath rocks in Badger Slough on 26 May 1985. The

collected eggs were placed within an Aquaclear 2000 filter for optimum water flow-through. Hatching occurred in 16-17 days at 17.0°C from the time of collection; it is not known, however, when fertilization took place. Sculpin developed rapidly after hatching, attaining juvenile status in three weeks. Samples of sculpin larvae were made every two or three days for two weeks, then were collected on a weekly basis.

Dolly Varden

Dolly Varden eggs and yolk-sac larvae were collected periodically by Saree Gregory and Don Martin from several sections of the Tiekkel River, north of Valdez. As these were wild caught, data on developmental times were not available.

Illustration Techniques

Illustrations are one of the most useful techniques for conveying descriptive information about fish larvae. Photographing fish larvae can produce imperfect results as specimens may have missing appendages or badly curled and deformed bodies due to the collection technique or the fixative. Also, the camera generally has a short optical depth of field so that fine features cannot be emphasized when attempting to get the entire specimen in focus (Faber and Gadd 1983). Illustration techniques, on the other hand,

can bring out the most important anatomical features, capture pigmentation patterns, and display myomeres. The artist can correct for sample imperfections and achieve the highest quality and detail regardless of depth of field; this can be coupled with written descriptions of pigmentation and morphometry. In short, illustrations are a superior alternative to photography.

One purpose of a larval fish illustration is to allow identification of unknown specimens. Since most specimens collected in the field are immediately fixed, then examined later for identification, I limited my drawing subjects to preserved specimens. If the purpose of a drawing is to document early ontogeny, however, it is necessary to draw from both live and preserved, photographed, and/or cleared and stained specimens. In this case, the skeletal system, the circulatory system, and other features which reveal the stages of early ontogeny are depicted (Balon 1985).

For each of the six species I collected, three views (dorsal, lateral, and ventral) of several stages of development were produced. These stages included at least one drawing of each of the phases in the larval period and one drawing of the early juvenile period. Arctic char and Dolly Varden, as with most salmonids, hatch in the mesolarval phase, therefore, no illustrations of the protolarval period exist for these species.

Specimens were studied and drawn under reflected, transmitted, and polarized light using a Wild Heerbrug stereoscopic microscope with a camera lucida attachment. A polarizing filter aided in emphasizing myomeres that otherwise were difficult to see. Transmitted light under the specimen and reflected light on the drawing paper were essential for properly tracing the specimen outline and features. Interested readers may refer to Jastrzebski (1985) for more information on the usage of camera lucida.

Preliminary illustrations were done with high magnification. The specimen was taken out of its preservative and placed in a Petri dish filled with distilled water. Glass beads placed in the holding chamber aided in positioning the fish for the different views. An initial tracing of the fish was then done in pencil. Because the whole specimen did not fit in the field of view of the scope, the drawing was done in overlapping sections which were then spliced together. The optical properties of the microscope, glass, and water lead to spherical distortion at all but the center field of view (Balon 1985). It was necessary, therefore, to continually shift the area of interest of the specimen to the center field of view.

The final illustrations were prepared by placing each spliced-together view (lateral, dorsal, and ventral) on a drafting board. Features such as the eyes, paired fins,

snout, and caudal fin were lined up and matched between each view with a straight edge. Mylar (drafting film) was placed over the penciled drawings, and technical pens containing permanent India ink were used to outline the basic shapes and important features. Internal structures such as the intestine or myosepta were represented by dotted lines. Stippling was used for shading to give the fish a more natural three dimensional aspect. I chose to use pen and ink versus other techniques such as ink wash or carbon dust because of the excellent photocopy and photographic reproducibility of the final product.

The drawings reflect as exact a rendition of pigmentation patterns as possible. These patterns, especially when combined with other descriptive features, can be valuable for identification purposes, but pigmentation is variable between individuals of the same species due to environmental conditions and diet (Moyle and Cech 1982, Snyder 1983).

Some illustrators, when working with badly curled or otherwise imperfect specimens, draw idealized versions by graphically "straightening" the drawing or using several specimens to composite a perfect specimen. I chose to draw exactly what I saw through the camera lucida to avoid mistakes in transcribing measurements. Additionally, I recorded morphometric measurements and wrote detailed descriptions for a minimum of two specimens for each

developmental phase for all the species collected.

Morphometric and Meristic Data

Many larval fish species are very similar in gross appearance and structure. To differentiate genera and species, it is often necessary to compare meristic data such as myomere and fin-ray counts, or to look at morphometric data such as the snout to vent length as a percentage of the total length. At each developmental stage, morphometric and meristic data were collected following procedures developed by the Larval Fish Laboratory (LFL) at Colorado State University in Fort Collins, Colorado. Measurements were made using a 10 mm eyepiece reticle (accurate to 0.05 mm), or for the larger specimens, a millimeter scale (accurate to 0.5 mm). Measurements were taken along a straight line parallel to the horizontal axis of the specimen, which is critical for accuracy (D. E. Snyder, LFL, personal communication, 1983). All measurements were made on the left side of the specimen. The morphometric data collected included 8 length measurements (Table 2) and are illustrated in Figure 2.

Meristic data included total and preanal myomere count at each developmental stage. The total number of myomeres were counted from the head region (beginning with the deltoid-shaped myomere just posterior to the occiput) to the last myomere on the notochord.

Table 2. Selected morphometric characters measured for early life phases.
 PR=protolarval phase, MS=mesolarval phase,
 MT=metalarval phase, JV=juvenile period.

Morphometric Characters		Life Phase			
		PR	MS	MT	JV
AS to:	anterior margin of snout to:				
AE	anterior margin of eye (snout length)	x	x	x	x
PE	posterior margin of eye (AE - PE = eye diameter)	x	x	x	x
OP1	anterior-most origin of pectoral fin (head length)	x	x	x	x
OP2	origin of pelvic fin (prepelvic length)		x	x	x
OD	origin of dorsal fin or finfold (predorsal length)	x	x	x	x
OA	origin of anal fin or finfold (preanal length)	x	x	x	x
SL	posterior margin of notochord or hypural plates (standard length)	x	x	x	x
TL	posterior margin of caudal fin (total length)	x	x	x	x

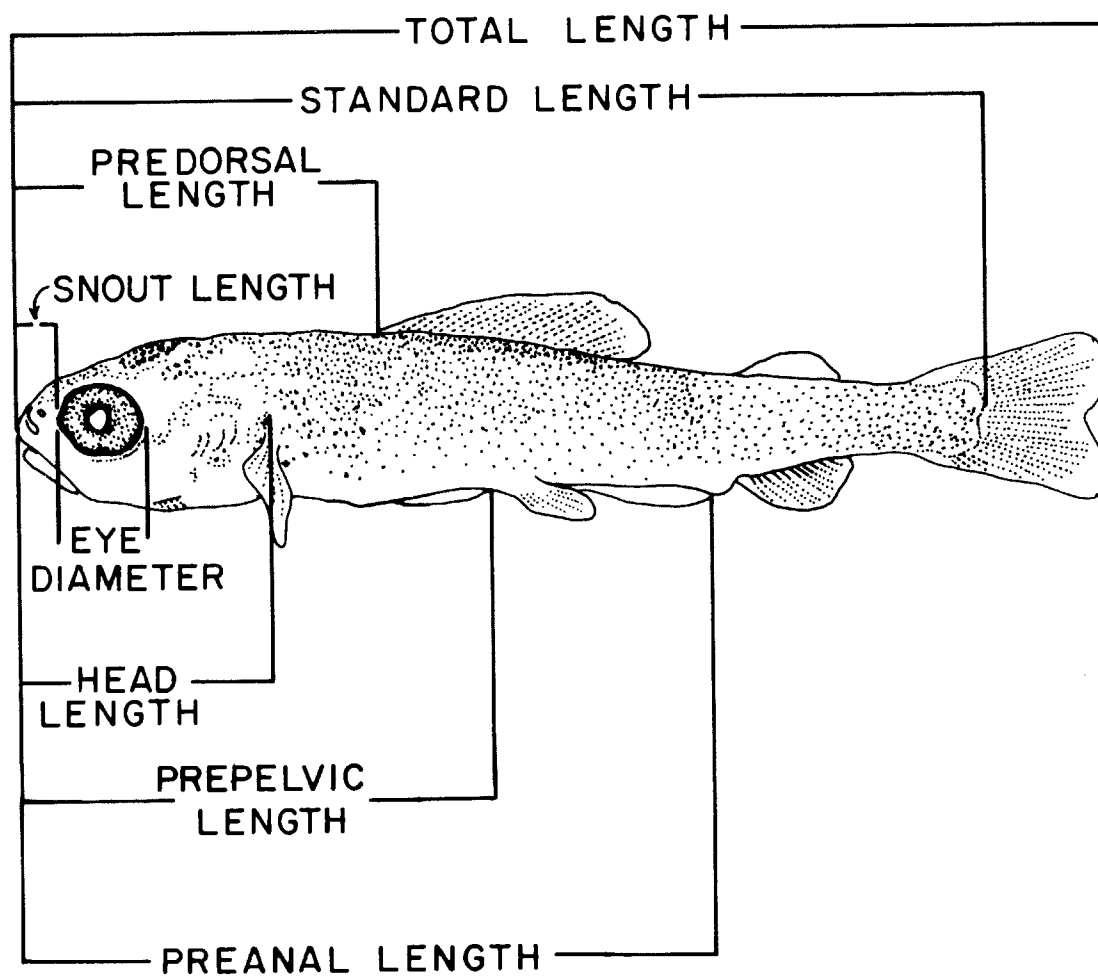


Figure 2. Idealized larva illustrating basic morphometric characters.

SPECIES PROFILES

In this section, I present a profile for each of the 23 species listed in Table 1. The profiles are organized by families and each consists of three sections: 1) Alaskan distribution and ecology, 2) spawning information, and 3) a description of early development from fertilization through the juvenile period. The last section includes information where available on meristics, morphometry, basic morphology, and pigmentation patterns of each species. Information in each profile was obtained from library research and in consultation with local fishery biologists most familiar with a particular species. The literature search was not an exhaustive review of each species, but instead focused on articles which gave specific information on early life history and emphasized information which would aid in identifying a species.

Original illustrations are included for the 6 species I raised or collected. Illustrations by other artists for the other 17 species, if available, are reprinted with permission.

Family Coregonidae

Whitefishes, widely distributed freshwater and anadromous fishes, are often treated as a subfamily of Salmonidae (Scott and Crossman 1973). I have chosen, however, to follow McPhail and Lindsey (1970) and place them in their own family. Many species are difficult to identify because of variability in characters such as shape, size, growth rate, number of scales, and gill rakers. These variations occur from lake to lake and are influenced by environmental conditions (Scott and Crossman 1973).

Sheefish

In Alaska, inconnu or more commonly, sheefish, are important for sport and subsistence use (Scott and Crossman 1973).

Distribution and Ecology

Range - In Alaska, sheefish are found throughout the Yukon River drainage including the Koyukuk, Porcupine, and Tanana rivers. They are also found in the Kuskokwim and Kobuk-Selawik river systems (Alt 1969).

Habitat - Anadromous, lake, and river resident populations of sheefish exist. The anadromous populations overwinter in coastal areas, and both the lake and the anadromous populations ascend rivers to spawn (Scott and Crossman 1973). Sheefish appear to be

most abundant in large, muddy rivers (McPhail and Lindsey 1970). Young need slow moving sloughs or deep waters of rivers which are biologically rich for optimum growth and survival (Alt 1973a).

Spawning

Location - In the Kobuk River, sheefish spawn in a relatively swift main current in a water depth of 1.2-2.7 m (optimally 1.5-1.8 m). The spawning substrate consists of various-sized gravel occasionally mixed with a small amount of sand which insures eggs becoming lodged in interstitial areas (Alt 1969). In the Yukon River, sheefish spawn in clearwater tributaries but also spawn in the main river between Beaver and Fort Yukon (Alt 1969, 1978, and 1986).

Nests - No nests or redds are built. The eggs are broadcast from near the water surface (Alt 1969).

Season - The spawning migration may begin right after breakup. Spawning occurs in September in the Kobuk River and in early October in the Yukon River system (Alt 1969). In the Kuskokwim, spawning occurs in late fall shortly before freezeup (Rae Baxter, Box 96, Bethel, Alaska, 99559, personal communication, 1986).

Sexual Dimorphism - No obvious external differences occur between sexes (McPhail and Lindsey 1970).

Age at Maturity - Sheefish become sexually mature late

in life. Alt (1969) found mature males between ages 5 and 9 with females maturing between 8 and 10 years. The youngest spawners were found in the Chatanika and Kuskokwim rivers and the oldest in the Selawik River system (Alt 1973a, Alt 1981). Baxter (personal communication) found age 5 spawners in the Kuskokwim area. Fecundity - Fecundity varies between 100,000 to 350,000 eggs per female. A notable exception is females of the Salmon Fork of the Black River in western Alaska which contain only 29,000 to 35,000 eggs (Alt 1969 and 1978).

Eggs

Description - Ovarian eggs average 2.5 mm in diameter (Alt 1969) but after fertilization they average 3.1 mm in diameter. The chorion is colorless, and the yolk is yellow to light amber. The yolk sac contains one oil droplet (Hinrichs 1979).

Incubation Period - Hinrichs (1979) describes development through hatching and reports an incubation period of 110 days at 4°C.

The Larval Period

Protolarval Phase - Newly hatched sheefish are 11-14 mm in length (Figure 3). Total myomeres range from 54 to 63 with 11-21 postanal myomeres. Morphometric measure-

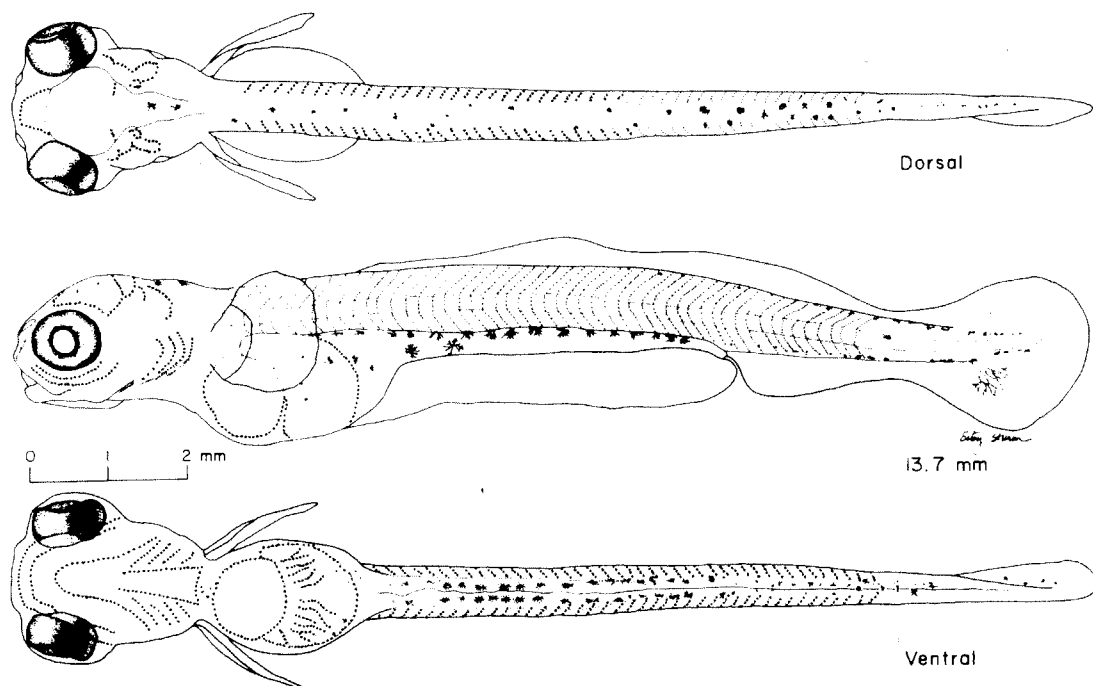


Figure 3. 13.7 mm newly hatched sheefish protolarva reared in a hatchery.

ments for all phases are presented in Table 3. The yolk sac is round with one large oil globule. Pelvic fins are absent. The mouth is terminal. Gill filaments noticeably protrude beyond the branchiostegals. Pigmentation is generally very light. On the dorsal surface, however, the melanophores are small, irregular, and stellate. They sparsely cover the anterior portion of the dorsal surface but increase in number towards the caudal fin. Large stellate melanophores are found on the dorsal surface of the intestinal tract (Hinrichs 1979, this study).

Mesolarval Phase - At 14 mm (Figure 4), there is an average of 60 myomeres with 16-20 postanal myomeres. The morphometry remains relatively unchanged. The yolk sac is half absorbed, and the notochord is slightly upturned. Four caudal rays are visible. Pelvic buds are apparent. Stellate melanophores are scattered over the dorsal surface of the gut and the ventral surface from the vent to the caudal fin. On the dorsal surface, scattered melanophores appear on the head. They increase in number from the mid region posteriorly to the caudal fin and extend to the tip of the notochord.

At 20 mm (Figure 5), fin-ray differentiation is apparent. Nine dorsal fin rays, 11 anal fin rays, and 20-21 caudal fin rays are apparent. The notochord

Table 3. Selected morphometric characters measured as a percent of total length for the early life phases of the sheefish. See Table 2 for definitions of morphometric characters.

PR = protolarva, MS1 = early mesolarva,
MS2 = late mesolarva, MT1 = early metalarva,
MT2 = late metalarva, JV = juvenile.

Morphometric Characters	<u>Life Phase</u>					
	PR	MS1	MS2	MT1	MT2	JV
n =	14	13	14	14	14	7
AS to:						
AE	1	2	2	3	4	4
PE - AE	7	6	7	7	6	5
OP1	17	17	20	22	21	20
OD	31	32	41	42	40	42
OP2	--	45	42	44	43	43
OA	68	67	65	65	62	63
SL	96	95	87	87	86	86

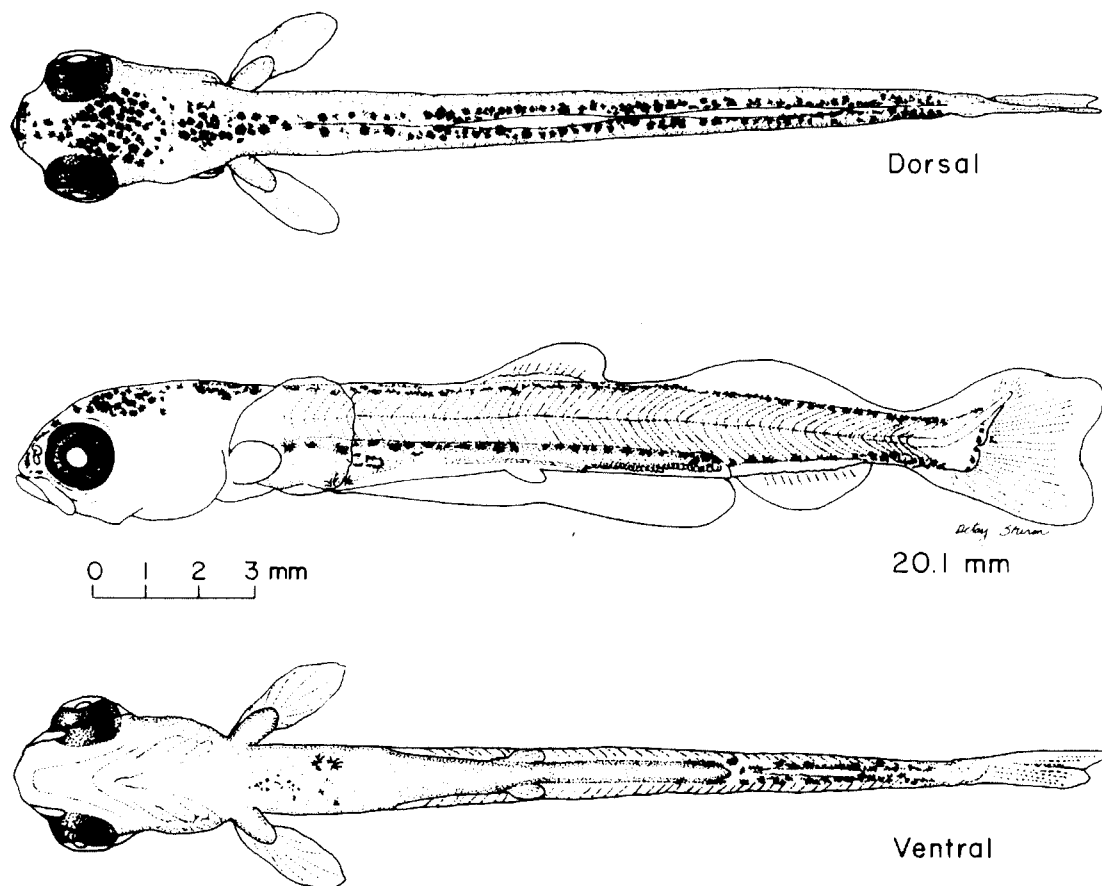


Figure 5. 20.1 mm sheefish mesolarva reared in the UAF laboratory.

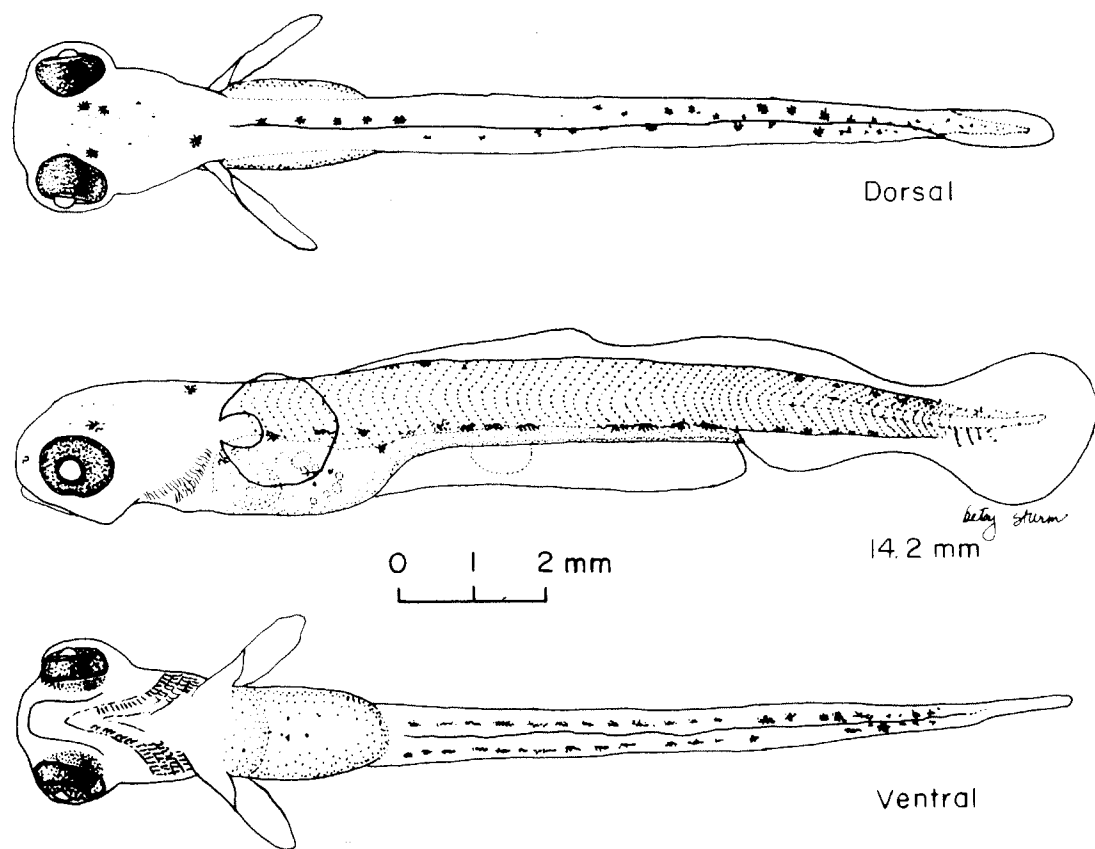


Figure 4. 14.2 mm sheefish mesolarva reared in a hatchery.

has upturned to a 45 degree angle. The lower jaw extends beyond the snout. On the dorsal surface, a dark patch of melanophores appears on the skull cap. Two rows of pigmentation paralleling the dorsal fin extend from the nape to the caudal fin. The caudal fin is sparsely pigmented. Irregularly spaced stellate melanophores cover the dorsal surface of the gut. Ventrally, small stellate and irregularly-shaped melanophores occur from the vent to the caudal peduncle.

At 23 mm (Figure 6), the head length has increased to 20% TL, the predorsal length to 41% TL, and the standard length to 96% TL. The dark patch on the head is more heart-shaped, but other pigmentation patterns remain relatively unchanged.

Metalarval Phase - At 28 mm (Figure 7), the morphology varies only slightly from the previous stage. Of note, however, is the increasing length of the snout. The upper surface of the snout has a slightly flattened appearance. Eleven to 12 dorsal fin rays, 20 principal caudal fin rays, 11 to 14 principal fin rays, 11 to 13 pectoral fin rays and 6 to 8 pelvic fin rays are present. Stellate melanophores line the dorsal surface of the gut. Some melanophores occur on the lateral line above the vent and extend towards the caudal fin. Pigmentation on the dorsal surface is similar to the

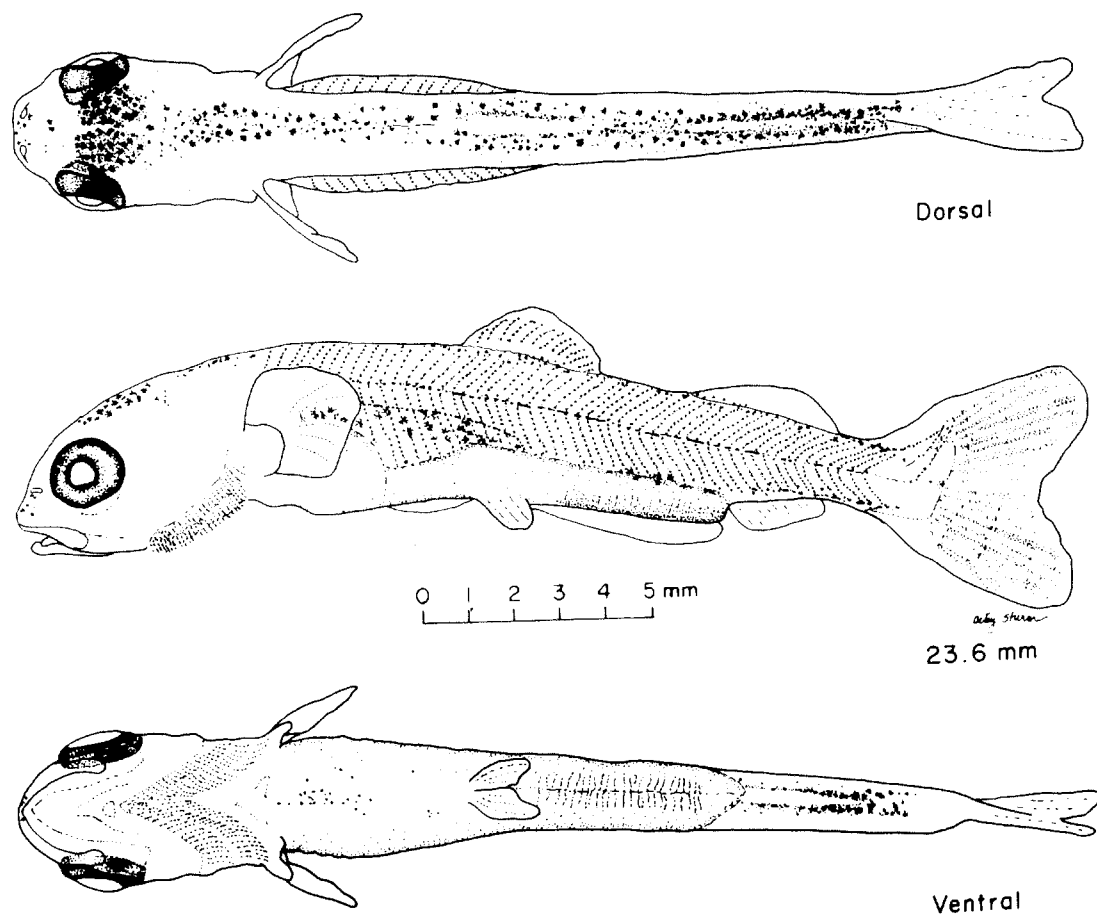


Figure 6. 23.6 mm sheefish mesolarva reared in a hatchery.

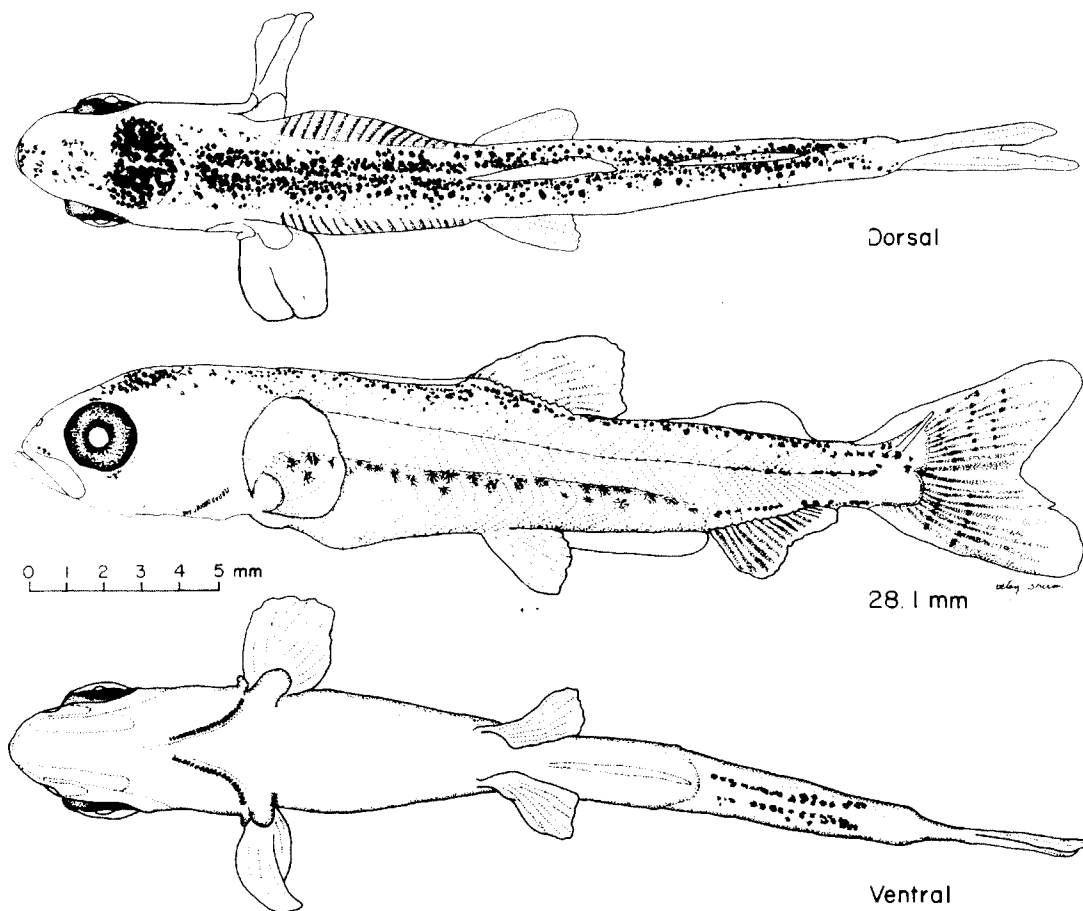


Figure 7. 28.1 mm sheefish mesolarva reared in a hatchery.

previous stage.

At 33 mm (Figure 8), the snout length has increased to 4% TL, but other morphometric measurements remain the same. Stellate melanophores cover the dorsal and lateral surface above the lateral line.

The Juvenile Period

At 47.0 mm, Hinrichs (1979) notes that scales are present, however, I could not see scales in my 54 mm specimens (Figure 9). The axillary process is not yet visible, but fin-ray differentiation is complete. The snout has a flatter appearance than in previous stages. Pigmentation above the lateral line is very dense.

Least Cisco

Least cisco are taken by subsistence fisheries and are popular with spear fishermen on the Chatanika River. The adults are distinguished from other whitefish by the superior mouth and the dark pectoral and pelvic fins (Morrow 1980; Baxter, personal communication).

Distribution and Ecology

Range - Least cisco are abundant in numerous lakes and streams of Interior Alaska north of the Alaska Range and, in addition, are distributed coastally from Demarcation Point in the Beaufort, Chukchi, and Bering

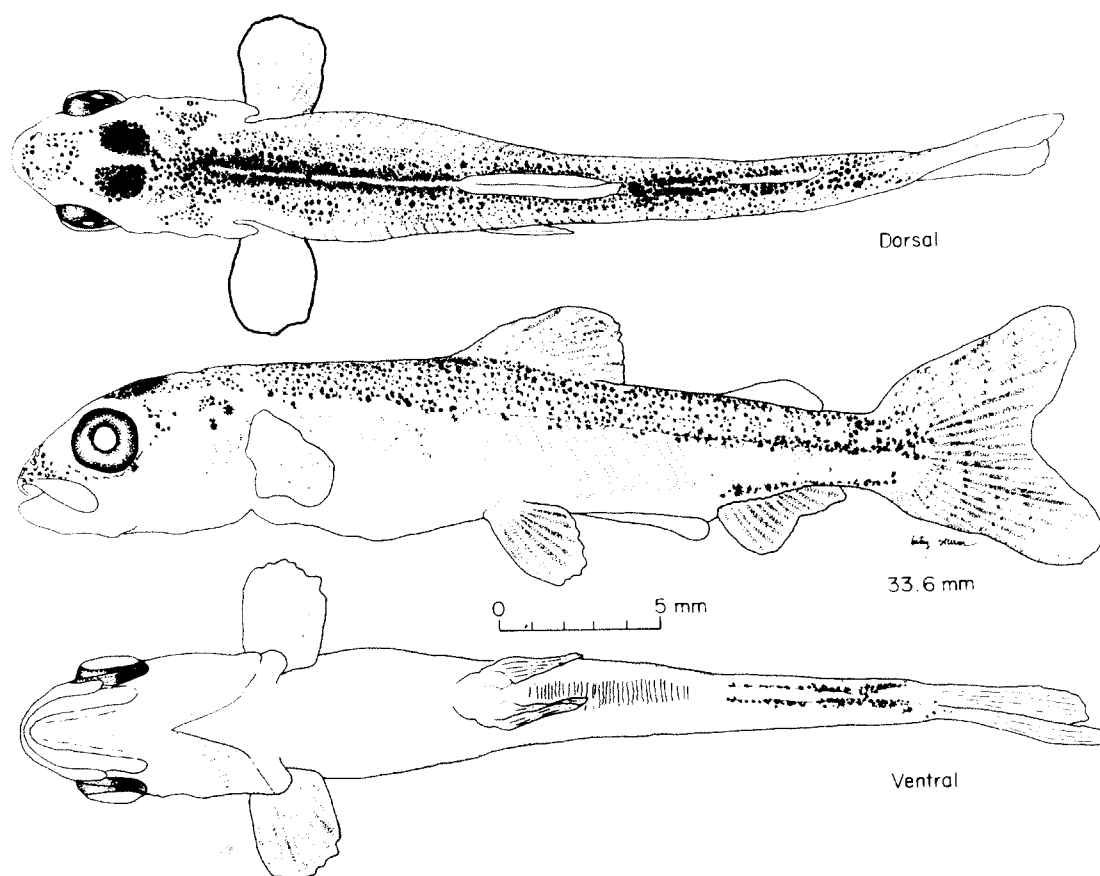


Figure 8. 33.6 mm sheefish metalarva reared in a hatchery.

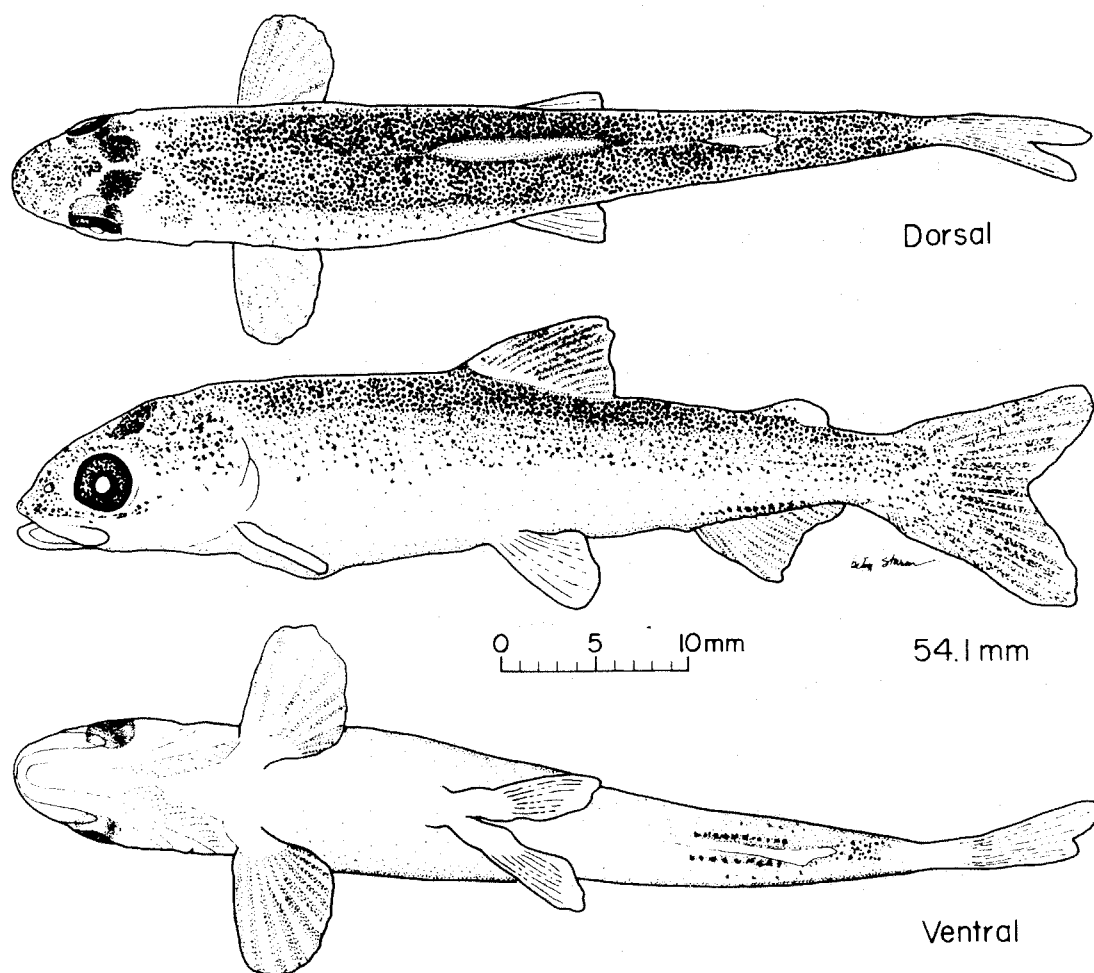


Figure 9. 54.1 mm sheefish juvenile reared in a hatchery.

seas to Bristol Bay (Alt 1971, Morrow 1980).

Habitat - The migratory form of the least cisco concentrates in river deltas of the coastal areas. The nonmigratory form stays in freshwater lakes or rivers (Berg 1948, Scott and Crossman 1973).

Spawning

Location - Least cisco migrate up river to areas with gravel and sand substrates suitable for spawning. Eggs are broadcast and settle between the gravel crevices. Lake bound cisco spawn in the littoral zone at depths no deeper than 1.5 meters (Berg 1948, Nikolskii 1961, Kepler 1973).

Nests - No nests or redds are built. Eggs and milt are broadcast near the water surface (Kepler 1973).

Season - Kepler (1973) notes that spawning movements up the Chatanika River occur in July and August with spawning occurring from mid-September to mid-October. In the Kuskokwim River area, cisco apparently spawn from mid-October to late November (Baxter, personal communication).

Sexual Dimorphism - Males may develop tubercles along the sides prior to the spawning season (McPhail and Lindsey 1970).

Age at Maturity - Least cisco collected in the Colville River delta reach maturity at ages 4 or 5 (Alt and

Kogl 1973). Alt (1971) found males maturing as early as age 2.

Fecundity - Kepler (1973) reports egg counts of the Chatanika River population to be between 27,800 and 93,500.

Eggs

Description - The eggs are demersal though not adhesive. They are bright orange in color and translucent when ripe. They measure less than 1 mm in diameter (Morrow 1980; Baxter, personal communication).

Incubation Period - Information not reported.

The Larval Period

No information is given on the early development except that hatching occurs in the early spring. The young migrate downstream in groups of 50-150 individuals even prior to the absorption of the yolk sac to feed in the lower reaches of rivers (Nikolskii 1961, Townsend and Kepler 1974).

Bering Cisco

Bering cisco and Arctic cisco differ in the number of gill rakers, pyloric caeca, and pored scales on the lateral line (Scott and Crossman 1973, Morrow 1980). There is much dispute as to whether two separate species actually exist

or whether the variability is due to environmental conditions. This thesis will treat these as separate species.

Distribution and Ecology

Range - Bering cisco are found from the Gulf of Alaska to Oliktok Point in the Beaufort Sea. They are most abundant near the coast. They have been collected in clear water tributaries of the Yukon River (Scott and Crossman 1973, Morrow 1980).

Habitat - Bering cisco, being anadromous, can be found in brackish lagoons and at the mouths of rivers. It is assumed that they overwinter in salt or brackish water but can migrate far upstream and may overwinter in deeper parts of rivers (Alt 1973b, Scott and Crossman 1973, Morrow 1980).

Spawning

Location - Bering cisco undertake extensive spawning migrations, with potential spawners found as much as 1400 km up river. The location of spawning grounds is unknown but it is presumed that spawning takes place in clear water tributaries or main rivers (Alt 1973b, Morrow 1980).

Nests - The information is not reported, however, as with most whitefishes, the eggs and milt are probably

broadcast by the adults (Scott and Crossman 1973).

Season - Potential spawners ascend large rivers during the summer, and therefore, spawning probably takes place in the fall (McPhail and Lindsey 1970, Alt 1973b, Morrow 1980).

Sexual Dimorphism - No obvious external differences have been noticed between the sexes. It is assumed that males develop spawning tubercles, however no spawning specimens have been collected (McPhail and Lindsey 1970).

Age at Maturity - Alt (1973b) reported that both males and females mature at age 4.

Fecundity - Information not reported.

Eggs

Description - Information not reported.

Incubation Period - Information not reported.

The Larval Period

Little is known of the early life history of Bering cisco except that the young probably hatch in the spring and descend downstream to feed in estuaries (Morrow 1980). No parr marks are found on the young (McPhail and Lindsey 1970).

Arctic Cisco

Arctic cisco have fewer gill rakers than Bering cisco but otherwise the two species are similar (Scott and Crossman 1973, Morrow 1980).

Distribution and Ecology

Range - In Alaska, Arctic cisco are found along the Arctic coast from Pt. Barrow eastward (Scott and Crossman 1973, Morrow 1980).

Habitat - Arctic cisco are anadromous, feeding in brackish waters or the lower reaches of muddy rivers. They migrate upstream in the summer to spawn and descend back to the delta to overwinter (Berg 1948, Nikolskii 1961, McPhail and Lindsey 1970).

Spawning

Location - The spawning grounds may be as far as 1600 km upstream from the overwintering and feeding areas (Galloway et al. 1983). Spawning occurs over gravel substrates in fairly swift water (Nikolskii 1961). Alt and Kogl (1973) suspected that spawners may enter the Colville delta in late summer to spawn. Craig and Haldorson (1981) surveyed the Colville River but failed to find any fish in spawning condition during the spawning period. Based on these data and other evidence, Galloway et al. (1983) proposed that Arctic

cisco leave the Colville Delta region when they approach sexual maturity and migrate to the Mackenzie River system to spawn.

Nests - No redd or nest is built. The eggs and milt are broadcast over a gravel substrate (McPhail and Lindsey 1970).

Season - Arctic cisco undertake spawning migrations in summer with spawning occurring in October and November (Berg 1948, Nikolskii 1961).

Sexual Dimorphism - Arctic cisco do not display any external differences between the sexes until spawning when the males develop flat tubercles along the sides of their body. These tubercles are absent or only weakly developed in females (McPhail and Lindsey 1970).

Age at Maturity - Craig and Haldorsen (1981) report that males reach sexual maturity at age 7, females at age 8. McPhail and Lindsey (1970) state that sexual maturity is reached at about age 4.

Fecundity - Fecundity varies between 7,700 and 90,000 eggs (Berg 1948, Nikolskii 1961).

Eggs

Description - Eggs of Arctic cisco from the Mackenzie River system vary in size from 0.6 mm in green females (Craig and Haldorsen 1981) to 2.3 mm for ripe females collected in the Liard River in October (personal

communication as cited by Galloway et al. 1983).

Incubation Period - Artificially-reared Irish pollan (Coregonus pollan), a conspecific of Arctic cisco (Ferguson et al. 1978), hatched about 91 days after fertilization at a temperature of 9.8°C.

The Larval Period

Information on the early life history of Arctic cisco is limited. Galloway et al. (1983) postulate that Arctic cisco spawn only in the Mackenzie River delta. Larvae hatch in spring and are apparently carried down river to the MacKenzie delta during ice breakup wherefrom they are transported into Alaskan waters via westward-flowing longshore currents.

No descriptions of the early developmental phases of Arctic cisco were found. A conspecific form, Coregonus pollan (Ferguson et al. 1978), however, was reared and brief descriptions of the early phases are presented here. The descriptions of the developmental phases were taken from Dabrowski (1981).

Protolarval Phase - Total length at hatching averages 10 mm (Figure 10a). The total myomere count is 58 with 37 preanal myomeres. The yolk sac is pigmented with stellate melanophores. Lines of pigmentation parallel the ventral finfold all the way to the anal region.

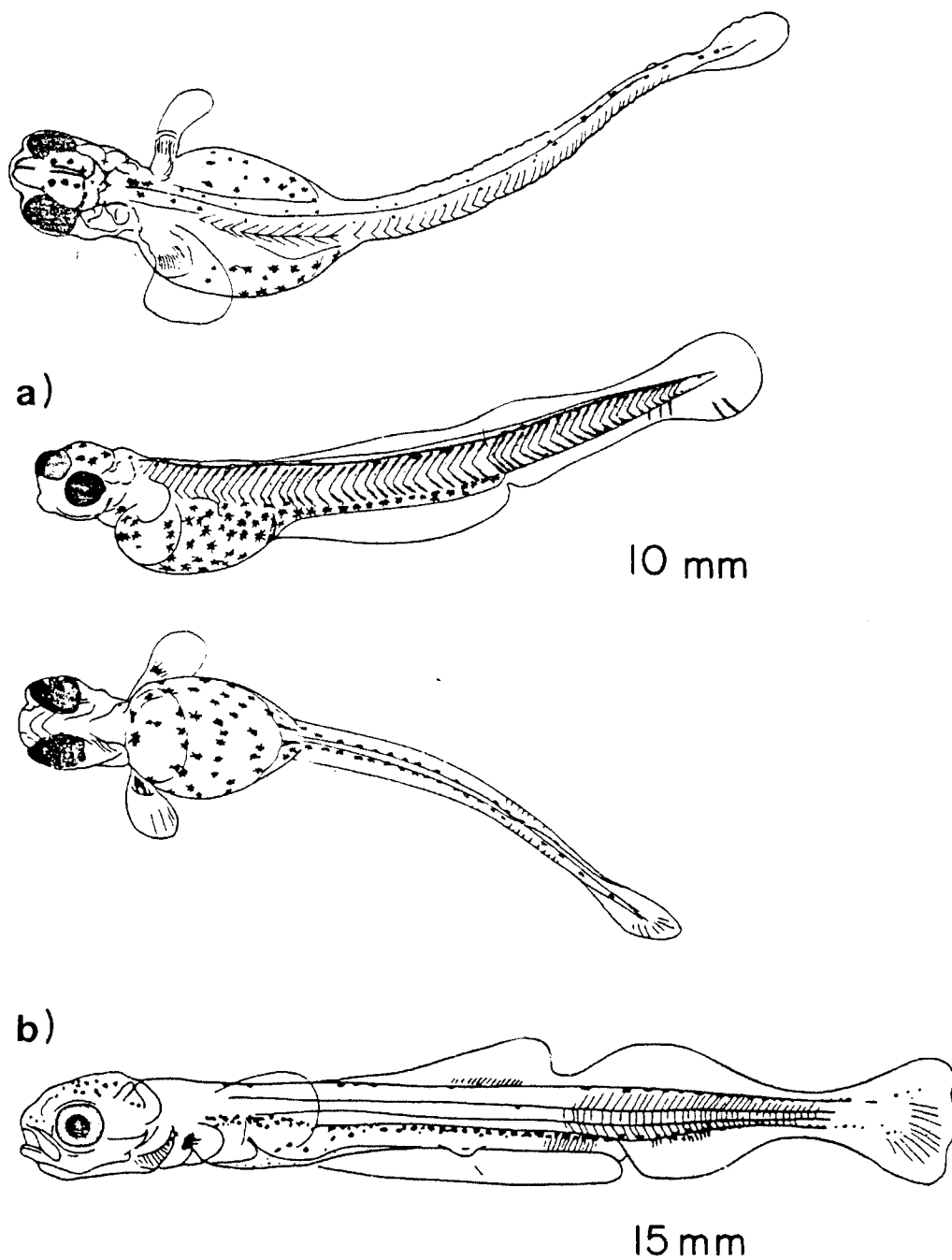


Figure 10. Larvae of the Irish pollan, a conspecific of Arctic cisco: a) newly hatched protolarva showing the dorsal, lateral and ventral views b) recently transformed mesolarva showing the differentiated finfold (both a and b reproduced from Dabrowski 1981, with permission).

Pectoral fins are present. The finfold is beginning to differentiate about the same time that the larvae begin to feed.

Mesolarval Phase - At 15 mm (Figure 10b), the yolk is nearly absorbed. The caudal fin begins to differentiate along with the principal rays of the dorsal and anal fins. The notochord is slightly upturned. Pelvic fin buds are visible.

At 19 mm (Figure 11a), the dorsal and adipose fins have separated. The swim bladder is still empty and is attached to the oesophagus. The anterior portion of the digestive tract is twisted, and the first loop is apparent.

Metalarval Phase - At 20 mm (Figure 11b), all principal rays have formed, though the preanal finfold is still evident. The swim bladder has partially filled.

The Juvenile Period

At 23 mm (Figure 11c), the swim bladder is completely filled. The ventral finfold has disappeared and all fin-ray differentiation is complete. The anterior part of the stomach has not yet evolved. No pyloric caeca are present. Between 30-32 mm, scales begin to form below the dorsal fin. By the time the juvenile is 36 mm in length (Figure 11d), the digestive tract has differentiated and most of the body is co-

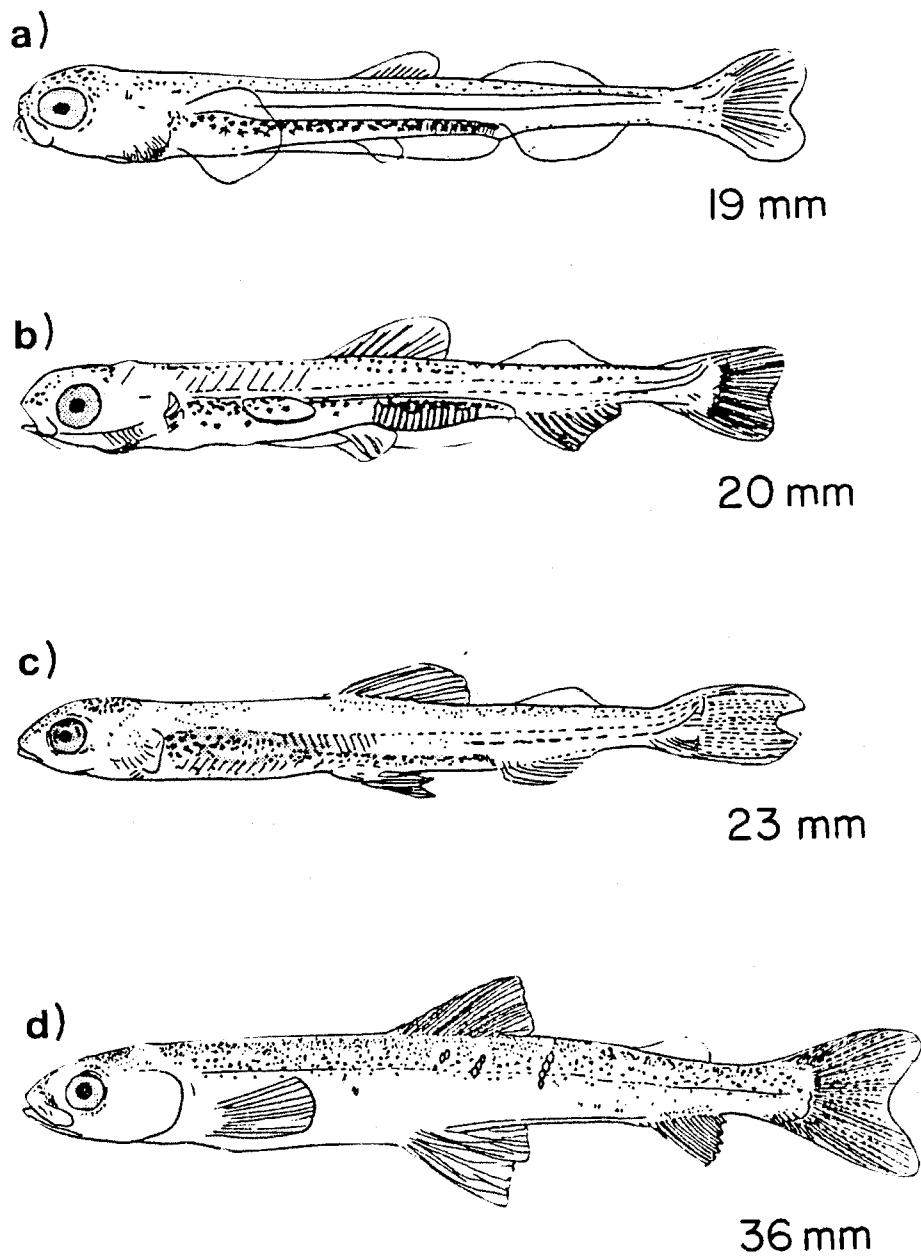


Figure 11. Larvae of the Irish pollan, a conspecific of Arctic cisco: a) mesolarva b) metalarva c) juvenile d) juvenile with fully developed fins (reproduced from Dabrowski 1981, with permission).

vered with scales.

Pygmy Whitefish

Pygmy whitefish are especially important as forage fish for Arctic char and Dolly Varden. In Alaska, it may compete for food with young sockeye salmon (Scott and Crossman 1973).

Distribution and Ecology

Range - In Alaska, pygmy whitefish have been found on the Alaska Peninsula (Chignik and Naknek river systems) and the Wood River system of Bristol Bay (Scott and Crossman 1973, Morrow 1980).

Habitat - This small whitefish thrives in lakes, rivers, and streams of mountainous regions. It is found both in shallow and deep waters of lakes and in clear or silty and moderate to fast flowing waters (McPhail and Lindsey 1970, Scott and Crossman 1973, Morrow 1980).

Spawning

Location - Spawning takes place in shallow areas of lakes or streams over gravel substrates (McPhail and Lindsey 1970, Scott and Crossman 1973, Morrow 1980).

Nests - The spawning behavior has not been observed. Eggs and milt are probably broadcast over the gravel

substrate and settle in interstitial crevices (McPhail and Lindsey 1970, Scott and Crossman 1973, Morrow 1980).

Season - Spawning takes place in late fall or early winter (Morrow 1980).

Sexual Dimorphism - Nuptial tubercles, occurring on the head, back sides and paired fins, form on both sexes, though the tubercles are weakly represented in the females (McPhail and Lindsey 1970, Scott and Crossman 1973).

Age at Maturity - Many males reach maturity at age 2, with the females maturing at age 3 (Eschmeyer and Bailey 1955, McPhail and Lindsey 1970).

Fecundity - Fecundity ranges from 90 to 1,200 (Eschmeyer and Bailey 1955, Heard and Hartman 1966, Morrow 1980).

Eggs

Description - Eggs are orange and average 2.6 mm in diameter when ripe (Booke 1970).

Incubation Period - Information not reported.

The Larval Period

Little is known of the early life history of pygmy whitefish, but Eschmeyer and Bailey (1955) described young collected in Lake Superior. It is not clear,

however, at what developmental stage these young were. A few melanophores are distributed on the lateral and dorsal surfaces of the head and body. The ventral portion is void of melanophores. Eight to 11 oval parr marks occur along the lateral line. The dorsal surface also is marked by an irregular series of about 12 to 14 dark spots.

Round Whitefish

In Alaska, round whitefish are important fish for subsistence use (Morrow 1980).

Distribution and Ecology

Range - Round whitefish are distributed throughout the mainland of Alaska from Juneau to the Arctic coast (Morrow 1980).

Habitat - Round whitefish are abundant in streams with gravel bottoms (Alt 1971) and in shallow areas of lakes (McPhail and Lindsey 1970). Krasikova (1968) remarked that river round whitefish preferred small, rocky, rapidly flowing streams.

Spawning

Location - Spawning grounds of round whitefish are gravel-covered bottoms found in shallow inshore areas of lakes, streams, and river mouths (Normandeau 1969, McPhail and Lindsey 1970, Alt and Kogl 1973, Scott and

Crossman 1973, Morrow 1980).

Nests - No nests or redds are constructed. Eggs and milt are broadcast over the spawning substrate where the eggs then settle in crevices between gravels (McPhail and Lindsey 1970, Morrow 1980).

Season - Spawning occurs in early winter in interior Alaska and fall in the more southerly areas (McPhail and Lindsey 1970, Scott and Crossman 1973, Morrow 1980).

Sexual Dimorphism - Nuptial tubercles develop strongly in rows along the sides of males, but more weakly on females (Normandeau 1969, McPhail and Lindsey 1970).

Age at Maturity - In Lake Michigan, Mraz (1964) found all age 4 fish mature with some males maturing at age 2. In New Hampshire, whitefishes attained sexual maturity at age 4 or 5 (Normandeau 1969).

Fecundity - Fecundity varies from 2,200 to 14,300 (Krasikova 1968, Normandeau 1969).

Eggs

Description - Unfertilized eggs are small yellow to orange spheres with a mean diameter of 2.7 mm but range from 3.1 to 3.9 mm after water absorption. Over 200 oil droplets are present in the yolk (Normandeau 1969, Booke 1970, Hinrichs 1979).

Incubation Period - Fertilization to hatching occurs

from 70 to 96 days at temperatures between 3 and 8°C and 140 days at 2°C (Normandeau 1969, Hinrichs 1979).

The Larval Period

Protolarval Phase - The mean length of newly hatched larvae is 12.3 mm live, 11.0 mm preserved (Hinrichs 1979) (Figure 12a). After hatching, larvae appear to remain in gravel for 1 to 2 weeks prior to feeding and heading downstream (Normandeau 1969). There are 35 preanal myomeres and 13 to 16 postanal myomeres (Faber 1970, Hinrichs 1979). Six to 12 oil droplets are present in the yolk. Pigmentation consists of an oval patch on the top of the head, two distinct rows of melanophores from the rear of the yolk sac to the anus along the intestinal tract, melanophores along the lateral line, and an irregular pattern on the dorsal finfold. The yolk sac length is 4.3 mm.

At 13 mm (Figures 12b), the yolk sac is half absorbed and larvae are beginning to feed. The urostyle has started to flex upward. Nares are present (Faber 1970, Hinrichs 1979).

Mesolarval Phase - At 19 mm (Figure 13a), stellate and contracted melanophores are found along the lateral line and parallel to the dorsal finfold. A circular cluster of melanophores is apparent just anterior to the base of the pectoral fin on the peritoneum

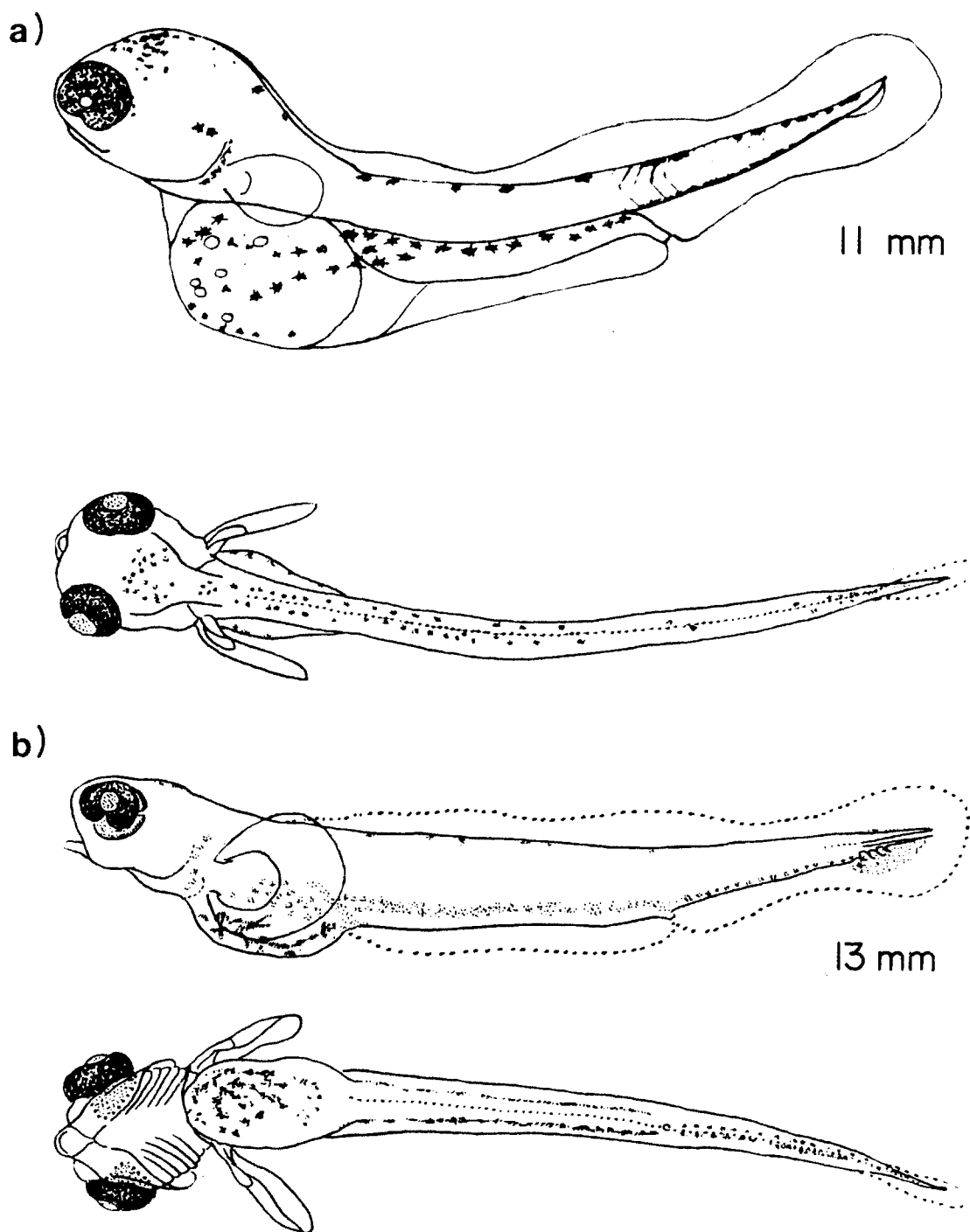
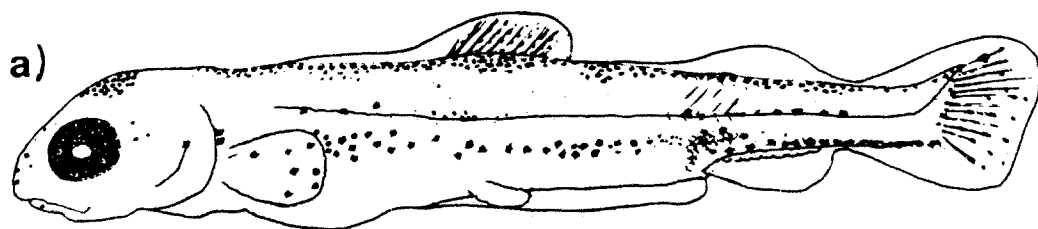
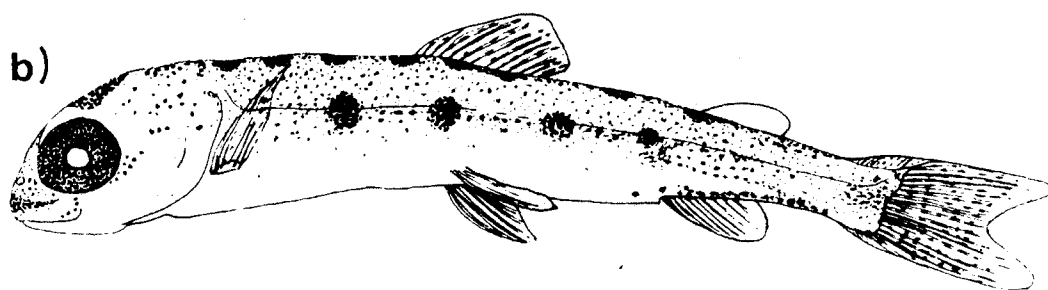


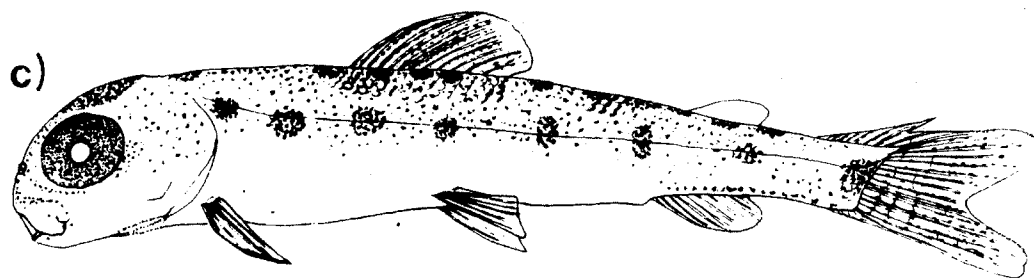
Figure 12. Larvae of the round whitefish: a) newly hatched protolarva (reproduced from Hinrichs 1979) b) 12.7 mm protolarva showing the dorsal, lateral, and ventral views (reproduced from Faber 1970, with permission).



19 mm



29 mm



43 mm

Figure 13. Larvae of the round whitefish: a) 19.2 mm mesolarva b) 26.8 mm metalarva c) 29 mm advanced metalarva d) 42.6 mm juvenile (reproduced from Hinrichs 1979).

(Hinrichs 1979).

Metalarval Phase - At 29 mm (Figure 13b), most fin rays have developed except in the paired fins. Pigmentation has increased to cover the entire dorsal surface and sides. A heart-shaped cap of pigmentation is present on the head (Hinrichs 1979).

At 35 mm, the full complement of rays is present on all fins except the pelvic fins. The finfold has been completely absorbed. Oval parr marks are present along the dorsal and lateral surfaces. Scales are forming on the lateral line (Hinrichs 1979).

The Juvenile Period

At 43 mm (Figure 13c), the larvae is fully scaled. Pigmentation has increased. Parr marks have also increased in density and number. Eight parr marks are present along the lateral surface (Hinrichs 1979).

Broad Whitefish

Broad whitefish, distinguished by a rounded snout which projects past the tip of the lower jaw, are taken for subsistence purposes in Alaska (Morrow 1980; Baxter, personal communication).

Distribution and Ecology

Range - In Alaska, broad whitefish are found in Bering

Sea drainages from the Kuskokwim River north, in the Yukon River and its tributaries, the Porcupine and Koyukuk rivers, and in the Chukchi Sea and Arctic Ocean drainages (McPhail and Lindsey 1970, Alt 1976, Morrow 1980).

Habitat - Broad whitefish are found mostly in rivers (McPhail and Lindsey 1970). They are anadromous in some areas, feeding in brackish waters of arctic drainages (Scott and Crossman 1973). They are found in most drainages where there is suitable spawning substrate, access to tundra lakes and ponds, and oxygenated water for winter survival (Baxter, personal communication).

Spawning

Location - Spawning occurs in river bottoms over gravel and sand substrates (Morrow 1980, Bogdanov 1983).

Nests - Information not reported.

Season - Upstream spawning runs of broad whitefish may begin as early as June and extend into September (Morrow 1980). In the Yukon tributaries, spawning has been observed in September (McPhail and Lindsey 1970). Kogl (1971) found that the spawning run peaked in July in the upper Colville with spawning suspected to begin in September. In the Kuskokwim River, spawning begins in October about the time the river freezes over (Baxter, personal communication).

Sexual Dimorphism - At spawning time, males develop rows of hard white conical tubercles on the head, fins, and surface of the body. Females develop tubercles to a lesser extent (Berg 1948, McPhail and Lindsey 1970). In spawning females, the first ray of the pectoral fin is an immaculate white whereas the other rays are dark (Berg 1948).

Age at Maturity - Alt (1976) reported that males reached maturity between ages 5 and 9 whereas females did not reach maturity until at least age 6.

Fecundity - Fecundity samples from the Kuskokwim River area varied from 46,000 to 127,000 (Baxter, personal communication).

Eggs

Description - Berg (1948) stated that the eggs are light yellow and about 4 mm in diameter. Baxter (personal communication) found reabsorbed eggs were 2.5 mm in diameter. When ripe, the eggs are a translucent cream color.

Incubation Period - Bogdanov (1983), who is the only author to incubate broad whitefish eggs under natural conditions, reported that the incubation period was at least 170 days.

The Larval Period

Protolarval Phase - Newly hatched broad whitefish average 12.3 mm in length (Figures 14a, 14b, and 14c). The large oval yolk sac has an oil globule occupying $\frac{1}{3}$ to $\frac{1}{2}$ of the yolk sac. The eyes are well developed. The body is tinted with transparent carotenoid pigments located mainly on the head and dorsal surface. Melanophores are concentrated on the dorsal and ventral surfaces. The shape of the melanophores varies from large stellate shapes to small condensed dots. Preanal myomeres range from 40-42 (Bogdanov 1983). The total myomere count ranges from 52-63 (Lebedeva 1976, as cited by Bogdanov 1984). The eye diameter is 7% TL, the yolk-sac is 11% TL, the head length is 14% TL, and the snout to vent length is 69% TL (Lebedeva and Meshkov 1980, as cited by Bogdanov 1983).

Mesolarval Phase - Information not reported.

Metalarval Phase - Information not reported.

The Juvenile Period

Young broad whitefish are reported to be pale in color and lack parr marks (McPhail and Lindsey 1970).

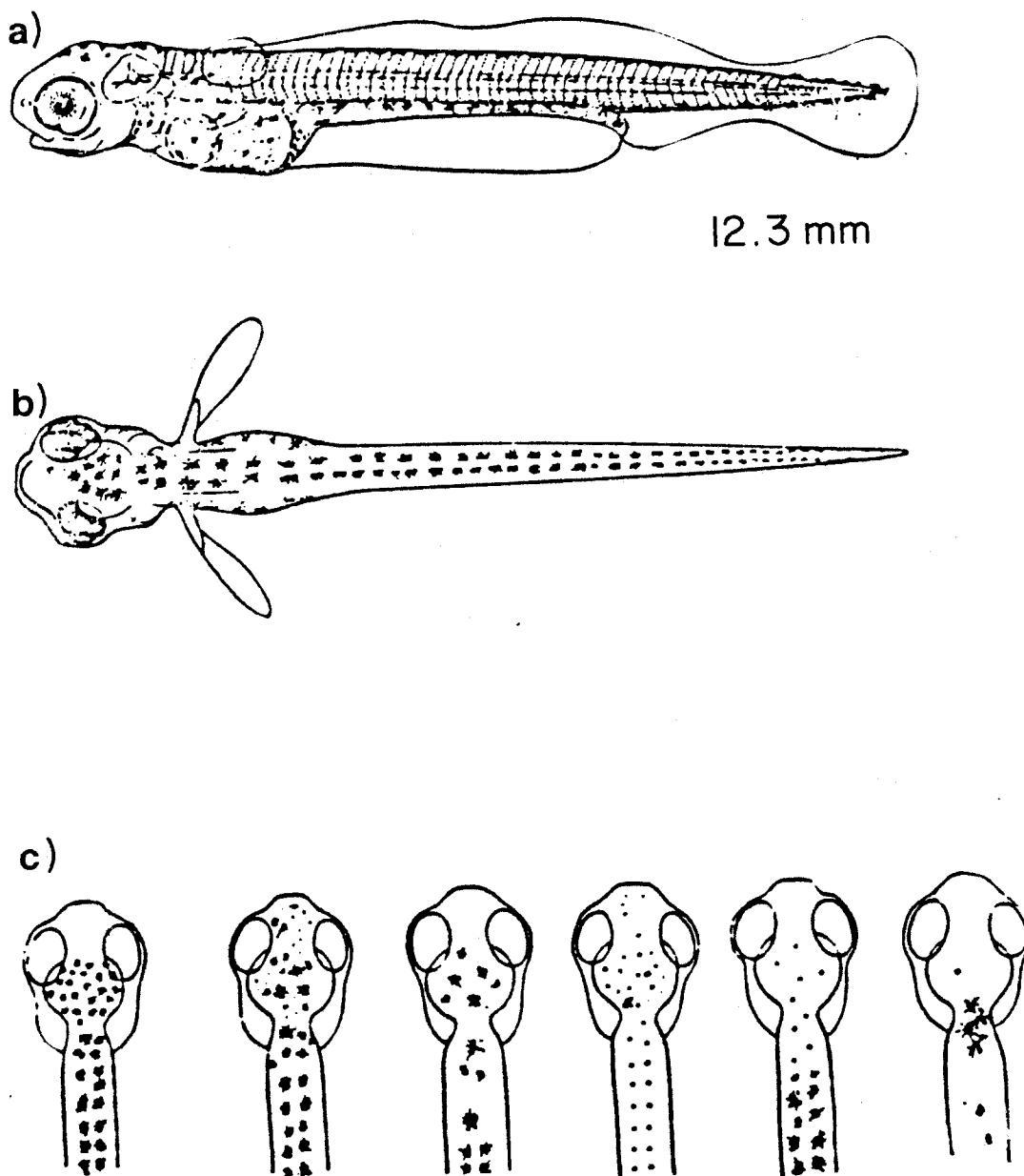


Figure 14. Larvae of the broad whitefish: a) lateral view of newly hatched larva, b) dorsal view of newly hatched larva, c) dorsal view of newly hatched larva showing variation in melanin pigmentation (reproduced from Bogdanov 1983, with permission).

Humpback Whitefishes

Humpback whitefishes, often called the Coregonus clupeaformis complex, have been divided into three species in Alaska: lake whitefish, humpback whitefish, and Alaska whitefish. The major distinguishing characteristic which divides these species is the modal number of gill rakers; humpback whitefish are listed with the lowest number of gill rakers and lake whitefish, the highest (McPhail and Lindsey 1970, Alt 1979, Morrow 1980). Because of the difficulty in distinguishing these three species and the belief by many that only one species truly exists in Alaskan waters (Baxter, personal communication), I have limited my discussion to humpback whitefish, the life history of which has been studied in Alaskan waters. For information on the larval period, however, only descriptions of lake whitefish exist.

Distribution and Ecology

Range - Humpback whitefish are in greatest abundance in the Yukon and Kuskokwim river drainages. Humpback whitefish are also found in coastal streams of western and arctic Alaska. They are found in various deep water lakes in the Interior and in some water bodies south of the Alaska Range including the Susitna, Copper, and Alsek rivers (McPhail and Lindsey 1970, Alt 1979).

Habitat - Humpback whitefish are found in lakes,

rivers, and in brackish waters off coastal areas. (McPhail and Lindsey 1970).

Spawning

Location - Spawning grounds are located upstream in the shallows of rivers or over rocky reefs in lakes (McPhail and Lindsey 1970). Spawning often occurs in moderately swift current at depths of 0.5-2.5 m over gravel or sand bottoms (Alt 1979).

Nests - Apparently, no nests or redds are constructed. Eggs and milt are broadcast over gravel or sand substrate. Fertilized eggs lodge in the crevices of the substrate (Alt 1979, Morrow 1980).

Season - Anadromous humpback whitefish undertake an upstream migration at the onset of ice breakup to feed in lakes and riverine sloughs, then continue slowly upstream to the spawning grounds. Spawning occurs in late September in the Kobuk River and mid-October in the Yukon. Spawning in the Chatanika River occurs from mid-September to mid-October. In deeper lakes in southern Alaska, spawning occurs as late as December or early January (Alt 1979). Spawning in the Kuskokwim River occurs from late October to mid-November (Baxter, personal communication).

Sexual Dimorphism At spawning time, males develop hard, white conical tubercles on the scales and head.

Tubercles are poorly developed or absent in females (McPhail and Lindsey 1970).

Age at Maturity - Humpback whitefish in the Chatanika River reach maturity at ages 4 and 5 whereas spawners in the Colville River delta mature between ages 8 and 10 (Alt and Kogl 1973).

Fecundity - Fecundity, which varies with fish size and area, ranges between 8,000 and 50,000 eggs per female (Morrow 1980).

Eggs

Description - Eggs are yellowish to pale orange with a diameter of 1.2 mm (Nikolskii 1961, McPhail and Lindsey 1970; Baxter, personal communication). For lake whitefish, Booke (1970) reports a diameter of 3.0 mm and a color of orange-yellow.

Incubation Period - Artificially-reared lake whitefish incubated at temperatures above normal, hatched between 56 and 79 days (Hinrichs 1979). When eggs were hatched in situ by various researchers (summarized by Auer 1982a), hatching time varied between 107 and 231 days. At 1.5°C, the approximate temperature eggs would develop in Alaskan waters, hatching occurred in 130-140 days (Auer 1982a).

The Larval Period

Young humpback whitefish apparently hatch during late winter or early spring. They are silvery in color and lack parr marks (McPhail and Lindsey 1970). This is the only information specifically relating to humpback whitefish early development. The following information is on lake whitefish early development.

Protolarval Phase - Newly hatched lake whitefish (Figure 15a and 15b) vary in length from 8 to 15 mm depending on environmental conditions. Auer (1982a) found that the most frequently reported lengths were between 12 and 13 mm TL. There are 38 to 43 preanal myomeres and 13 to 17 postanal myomeres (Faber 1970, Fudge et al. 1986). The eye diameter is 5-6% TL, the head length is 13% TL, the origin of the dorsal finfold is 20-30% TL, and the preanal length is 63-68% TL (Hart 1930, as cited by Auer 1982a). One oil droplet or several small droplets are evident in the yolk sac. The mouth is subterminal. Melanophores are present on the head, in rows parallel to the dorsal finfold, surrounding the notochord, and along the ventral finfold posterior to the anus. Stellate melanophores can be seen on the intestinal tract (Hinrichs 1979).

Mesolarval Phase - At 13 mm (Figure 15c and 16a), 10 rays are present on the caudal fin. The pelvic buds

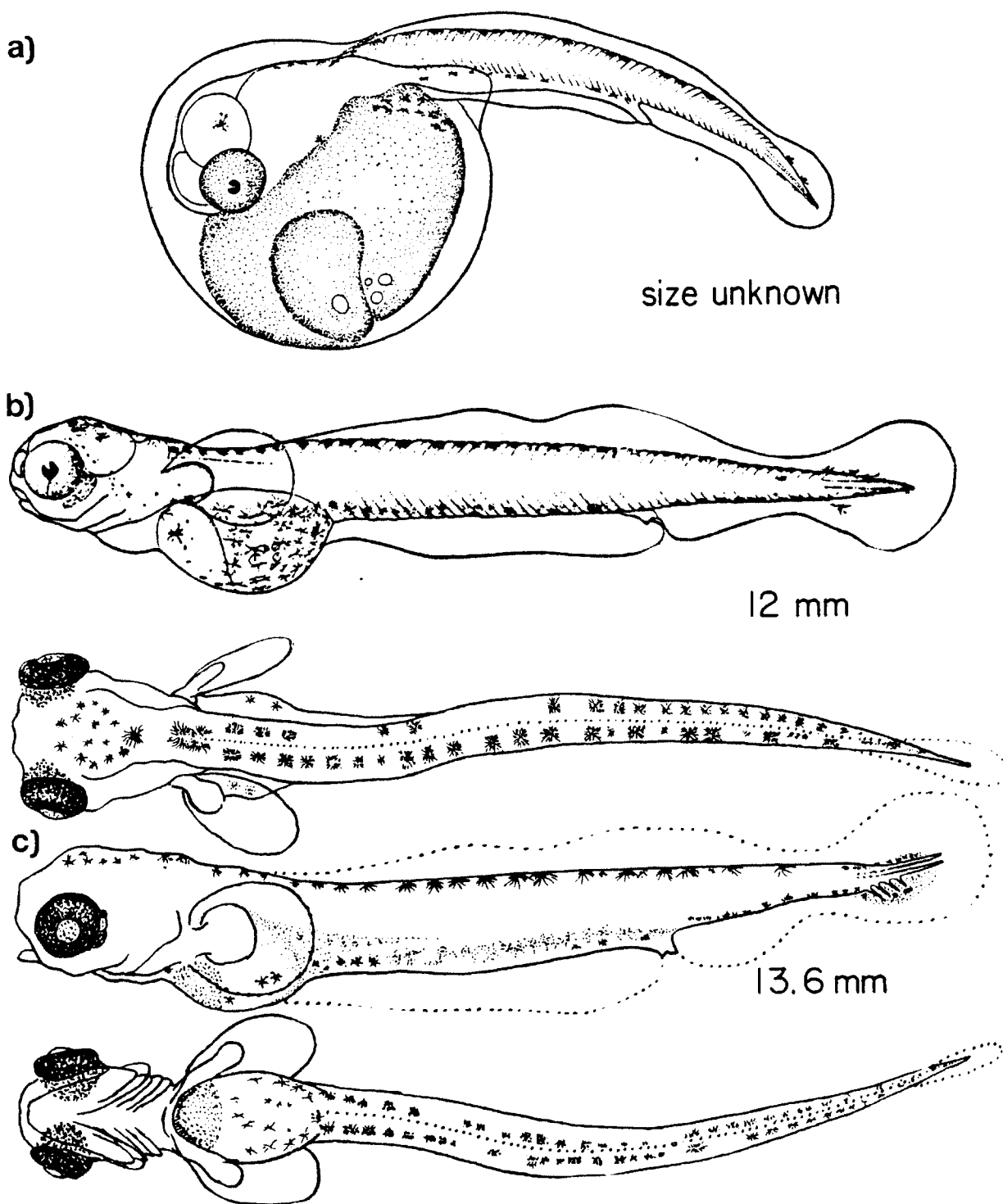


Figure 15. Larvae of the lake whitefish: a) protolarva with yolk sac b) 12 mm protolarva (both a and b reproduced from Fish 1932) c) 13.6 mm mesolarva showing the dorsal, lateral, and ventral views (c reproduced from Faber 1970, with permission).

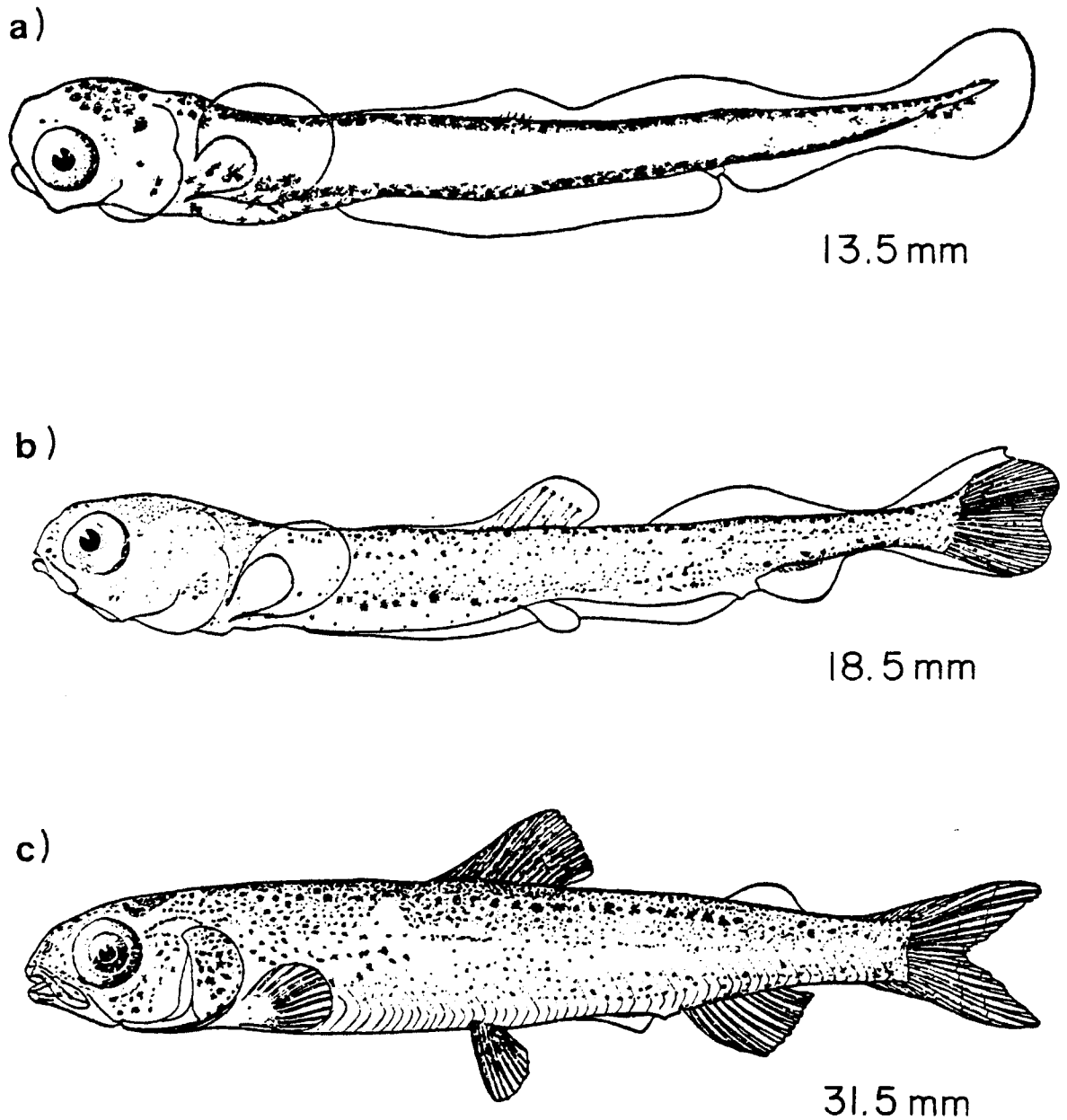


Figure 16. Larvae of lake whitefish: a) 13.5 mm mesolarva b) 18.5 mm metalarva c) 31.5 mm metalarva (a, b, and c reproduced from Fish 1932).

have not yet formed, nor have the dorsal and anal fin rays.

At 18 mm (Figure 16b), there is increased pigmentation. Melanophores occur on the snout, opercle, and posterior half of the lateral line. The notochord is upturned to a 45 degree angle. Pelvic fins are apparent, and most of the yolk sac is absorbed. The adipose and dorsal fins are now distinct (Hinrichs 1979). Cucin and Faber (1985) report that fin rays on the dorsal and anal fins are now visible.

Metalarval Phase - At 23 mm, the caudal fin is forked. The snout is pointed. Contracted, small melanophores have increased along the dorsal margin of the intestine and above the lateral line. Melanophores are present on the caudal fins. The preanal finfold is still present and rows of melanophores have appeared on gill arches (Hinrichs 1979). The eye diameter is 7% TL, head length is 18-19% TL, predorsal length is 42-49% TL, and preanal length is 67-69% TL. The mouth is distinctly inferior (Hart 1930, as cited by Auer 1982a).

At 32 mm (Figure 16c), a heart-shaped pattern of contracted pigments is present on the head. The larva is silvery gray in color (Hinrichs 1979). Pigmentation is apparent everywhere except the ventral surface.

Parr marks are evident (Hart 1930, as cited by Auer 1982a).

The Juvenile Period

Between 34-54 mm TL, the eye diameter is 6% TL, head length is 21% TL, predorsal length is 40% TL, and preanal length is 64% TL (Hart 1930, as cited by Auer 1982a).


Family Salmonidae

The salmon family, Salmonidae, is composed of salmon, trouts, and chars. These freshwater and anadromous fishes are extremely important commercially. The chars, the only members of this family which I am including in this thesis, are important sport fish (Scott and Crossman 1973, Morrow 1980).

Arctic Char and Dolly Varden

The taxonomy of the Dolly Varden-Arctic char complex is confusing. Within each species are anadromous and resident populations with northern and southern forms which differ in the mean number of pyloric caeca and gill rakers. Savvaitova (1980) states that these differences are a function of environmental conditions. The number of gill rakers depends on the local abundance and size of the food items. The number of pyloric caeca is temperature related. At higher temperatures, fewer caeca are produced. McPhail and Lindsey (1970) separate the species because where the two species overlap, they are physically distinguishable. They also do not appear to hybridize in nature. Because of the confusion with this complex, however, I am combining both species into one profile and using the general term "char." The larval development of each species is described separately, however.

Distribution and Ecology

Range - Char are found throughout Alaska. The anadromous forms of char occur in coastal drainages from southeast Alaska to the Beaufort Sea (Alt 1978, Morrow 1980, Alt 1981, DeCicco 1985). Lake resident char are found in lakes of the Kamchatka Peninsula and Brooks Range but are rare in coastal plain lakes. Spring resident populations are found in the Beaufort Sea drainages. The northern form of river resident populations is found north and east  the Alaska Range. The southern form is found south of the Alaska Range including the Aleutian Islands (Morrow 1980, Bendock and Burr 1986).

Habitat - Char can be found in almost all types of fresh and salt waters but rarely occur in muddy water (McPhail and Lindsey 1970, Armstrong and Morrow 1980).

Spawning

Location - Char spawn over gravel or rocky shoals of lakes or in deep pools of rivers (Scott and Crossman 1973).

Nests - A redd is dug by the female in a medium to large gravel-bottomed stream with a moderate current. The redds are usually 30-60 cm in diameter, may be 30 cm deep, and are placed at least 6 m apart (Scott and Crossman 1973).

Season - Char spawn from late August to early November depending on the area (Scott and Crossman 1973, Morrow 1980, Armstrong and Morrow 1980).

Sexual Dimorphism - Spawning males develop a pronounced kype. Both sexes develop bright orange to red colors on the lower sides and belly with bright red spots on the dorsal and lateral surfaces. The colors are more intense and brilliant in the males (Armstrong and Morrow 1980).

Age at Maturity - In general, sexual maturity is reached between ages 3 and 6. Lake resident char from the North Slope mature between ages 5 and 10 (Scott and Crossman 1973, Armstrong and Morrow 1980, Bendock and Burr 1986).

Fecundity - Anadromous northern char produce 1,500 to 7,000 eggs, but the nonanadromous northern form only produce up to 350 eggs. The southern anadromous form produces around 1,800 eggs whereas the nonanadromous form only produces about 60 eggs. The fecundity of lake resident char is between 290 and 1,600 (Armstrong and Morrow 1980, Bendock and Burr 1986).

Eggs

Description - Eyed Arctic char eggs from Amiloyak Lake average 6.2 mm in diameter and are pale orange. In contrast, recently spawned Dolly Varden eggs from the

Tiekel River average 4.0 mm, are a creamy yellow, and slightly oblong (this study). Eggs from northern anadromous Dolly Varden range from 3.5 to 6.0 mm in diameter. Eggs from northern freshwater stock vary between 2.8 and 4.0 mm in diameter (Armstrong and Morrow 1980).

Incubation Period - Hatching occurs between 125 and 136 days at water temperatures of 2.2-8.3°C. Development time for northern Dolly Varden is 7-8 months (Armstrong and Morrow 1980). Arctic char eggs from Amiloyak Lake took about 125 days to develop at 3°C (Bendock and Burr 1986). Armstrong and Blackett (1980) summarized the development of Dolly Varden from the first cell division through first hatching.

The Larval Period - Arctic Char

Mesolarval Phase - Newly hatched Arctic char average 19 mm in length (Figure 17). Fifty-five myomeres are visible under a polarizing filter with 19 postanal myomeres. Morphometric measurements are given in Table 4. Pelvic buds are visible. Fin ray differentiation is apparent on the caudal fin. The yolk sac is large, has numerous oil globules, and is orange. Pigmentation is dense on the dorsal surface. An oval pattern of melanophores is apparent on the skull cap. Dense

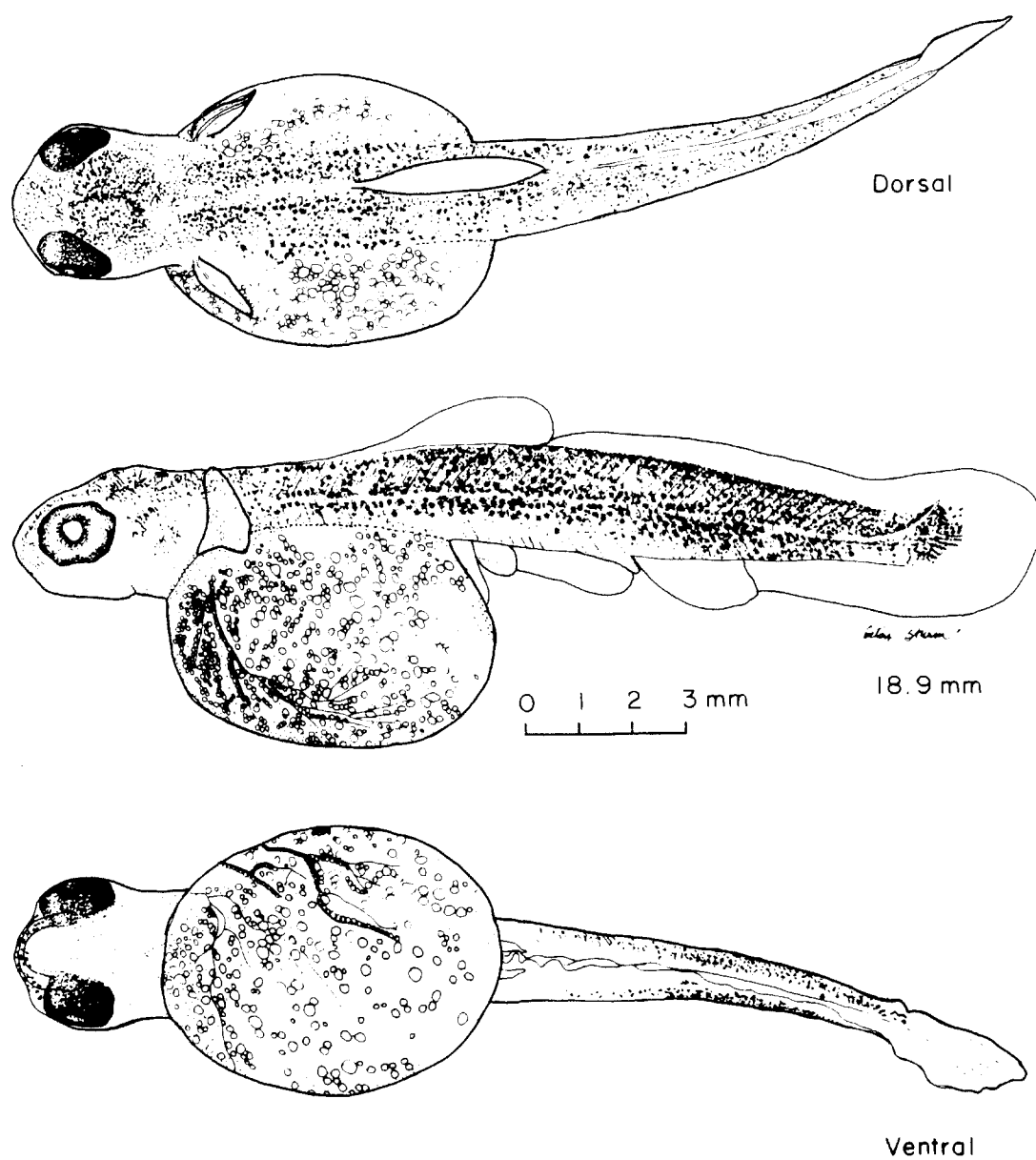


Figure 17. 18.9 mm newly hatched Arctic char mesolarva reared in a hatchery.

Table 4. Selected morphometric characters measured as a percent of total length for the early life phases of Arctic char. See Table 2 for definitions of morphometric characters.
 MS = mesolarva, MT1 = early metalarva
 MT2 = late metalarva.

Morphometric Characters	<u>Life Phase</u>		
	MS	MT1	MT2
n =	9	3	8
AS to:			
AE	2	2	2
PE - AE	6	7	7
OP1	17	17	18
OD	33	38	39
OP2	44	46	45
OA	60	61	61
SL	89	88	87

stellate melanophores cover the rest of the dorsal surface and most of the lateral surface. No parr marks are evident.

Metalarval Phase - At 22 mm (Figure 18), the morphometry is similar to the previous stage except that the predorsal length has increased to 38% TL. The yolk sac is still prominent and a pale creamy orange. Eleven to 12 dorsal fin rays, 19 to 20 principal caudal fin rays, 9 anal fin rays, 9 to 10 pectoral fin rays, and 5 pelvic fin rays are apparent. Six to 9 irregularly-sized parr marks are evident. Melanophores outline some dorsal fin rays and appear in the area of the future adipose fin.

At 26 mm (Figure 19), the morphometry remains relatively unchanged. The yolk sac is nearly absorbed. Twelve principal dorsal fin rays, 11 anal fin rays, 20 principal caudal fin rays, 9 to 10 pectoral fin rays, and 7 pelvic fin rays are visible. In cleared specimens, 65 vertebrae were counted. Six to 9 irregularly-sized parr marks are evident. The adipose fin is present, and the posterior portion of it is pigmented.

The Juvenile Period

No specimens were available.

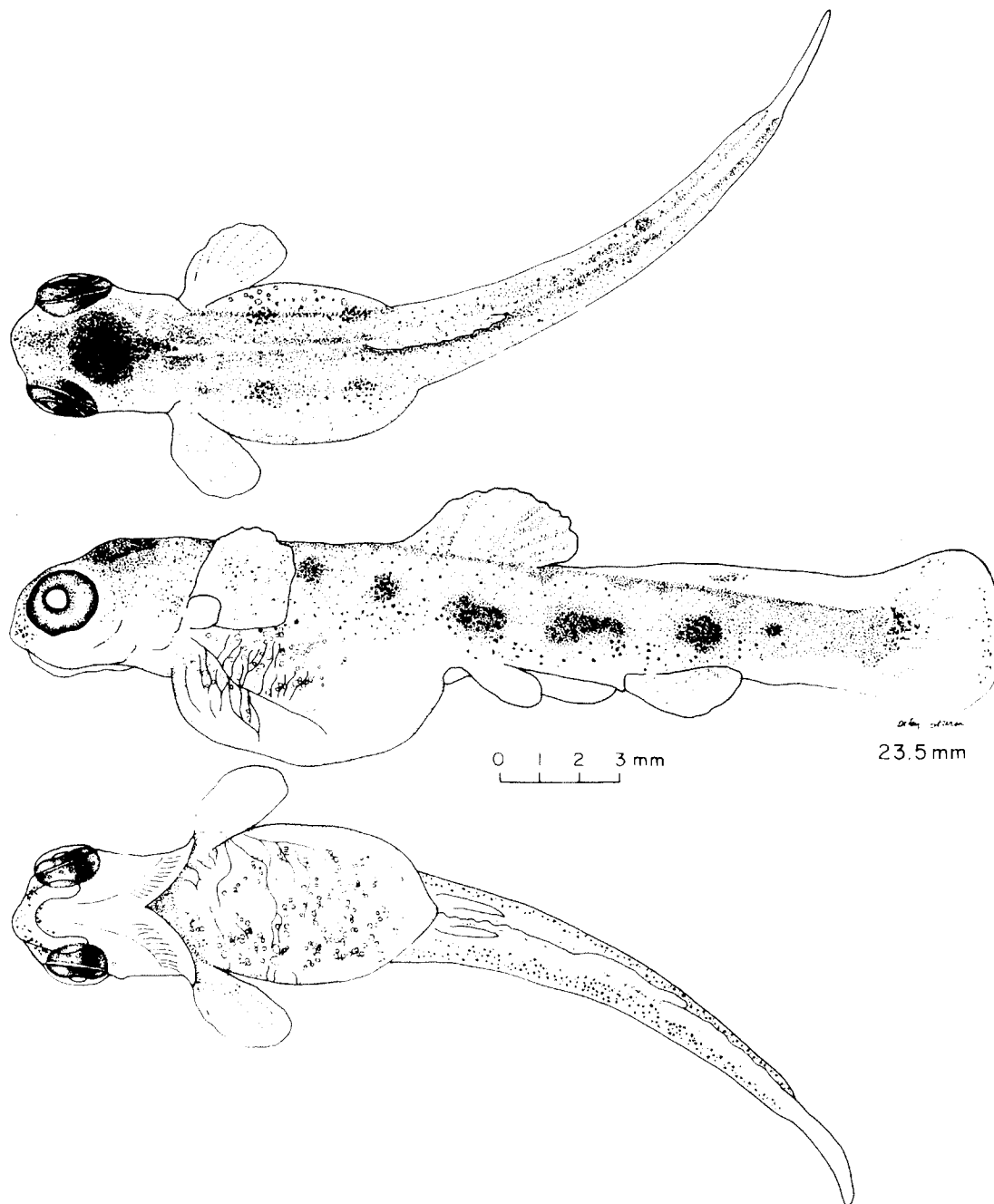


Figure 18. 23.5 mm Arctic char metalarva reared in a hatchery.

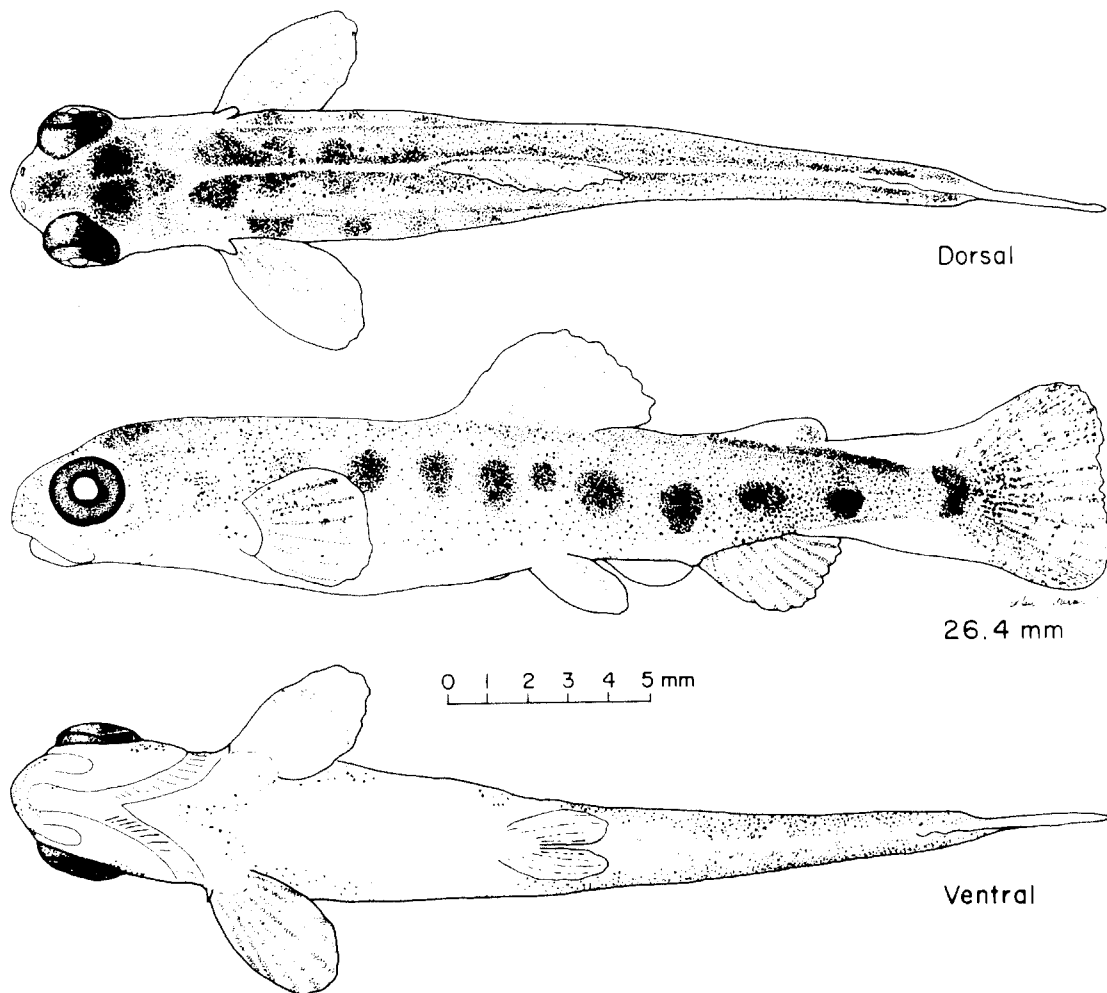


Figure 19. 26.4 mm Arctic char metalarva reared in a hatchery.

The Larval Period - Dolly Varden

Mesolarval Phase - Newly hatched Dolly Varden from Baranof Island in southeastern Alaska average 16.5 mm in length (Armstrong and Blackett 1980). At 18 mm (Figure 20), the size at which Dolly Varden were collected from a redd in the Tiekel River, the yolk sac has numerous oil globules and is a pale yellow. It is partially absorbed. Sixty myomeres are visible. Morphometric measurements are given in Table 5. Eleven to 12 dorsal fin rays, 13 caudal fin rays, and 6 anal fin rays are apparent. Pigmentation is dense with a dark patch on the skull cap and 6-8 faint parr marks evident on some specimens.

Metalarval Phase - At 20 mm (Figure 21), the yolk sac is now absorbed. The morphometry is similar to the previous stage except that the standard length has decreased to 87% TL. The pigmentation is darker than the previous stage, but the patterns are similar. The 8-10 parr marks are evident.

At 26 mm (Figure 22), morphometric measurements remain relatively unchanged. There are 11 to 13 dorsal fin rays, 9 to 11 anal fin rays, 19 to 20 principal caudal fin rays, 12 pectoral fin rays, and 8 pelvic fin rays. A cleared specimen had 62 vertebrae. Pigmentation is similar to the other phases except that the

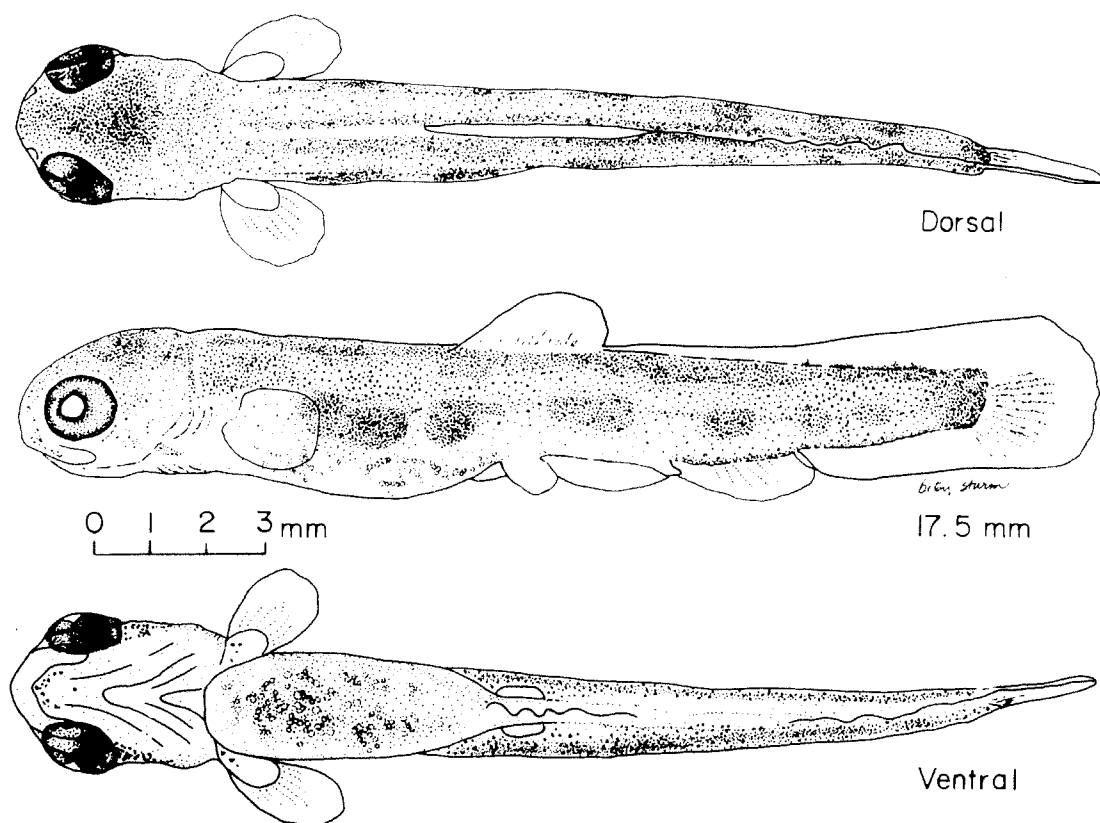


Figure 20. 17.5 mm Dolly Varden mesolarva collected from the Tiekel River, Alaska.

Table 5. Selected morphometric characters measured as a percent of total length for the early life phases of Dolly Varden. See Table 2 for definitions of morphometric characters.
 MS = mesolarva, MT1 = early metalarva,
 MT2 = late metalarva, JV = juvenile.

Morphometric Characters	<u>Life Phase</u>			
	MS	MT1	MT2	JV
n =	6	4	7	10
AS to:				
AE	3	2	3	3
PE - AE	6	7	5	5
OP1	18	20	20	19
OD	38	39	40	41
OP2	44	42	44	45
OA	61	60	61	62
SL	90	87	86	85

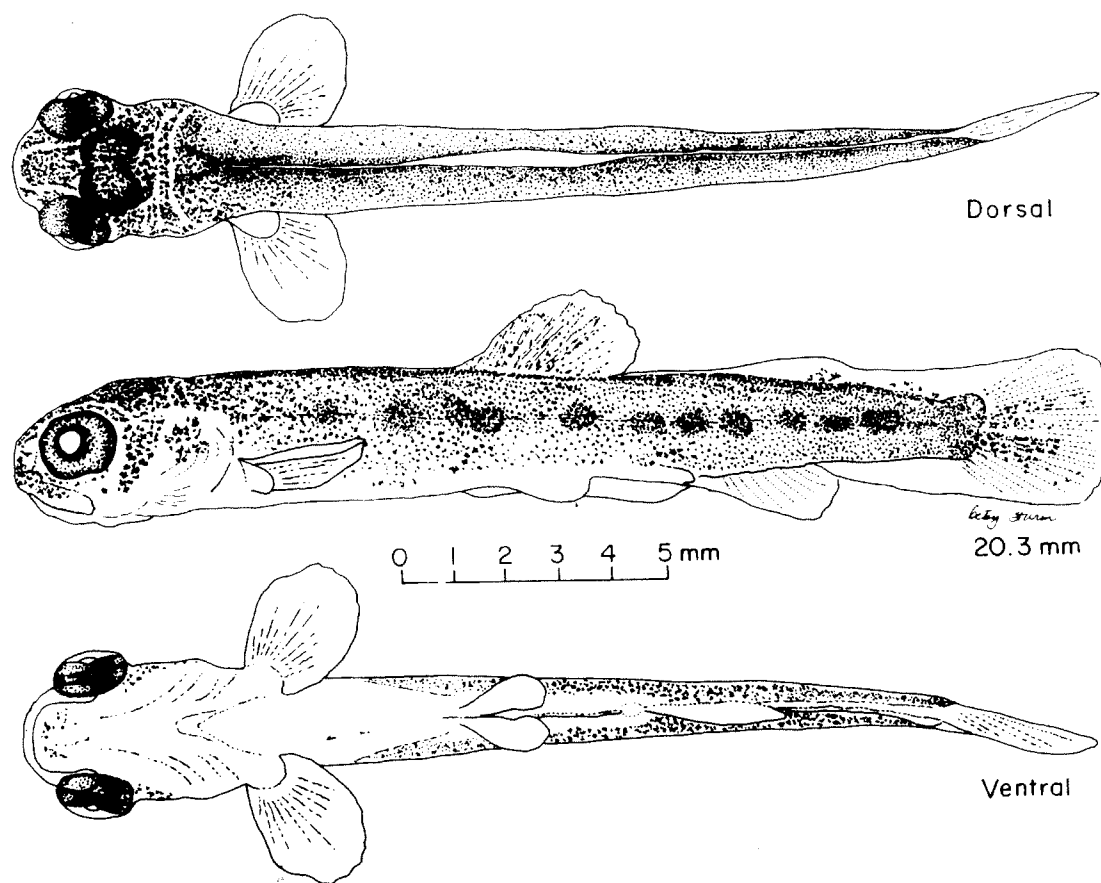


Figure 21. 20.3 mm Dolly Varden metalarva reared in the UAF laboratory.

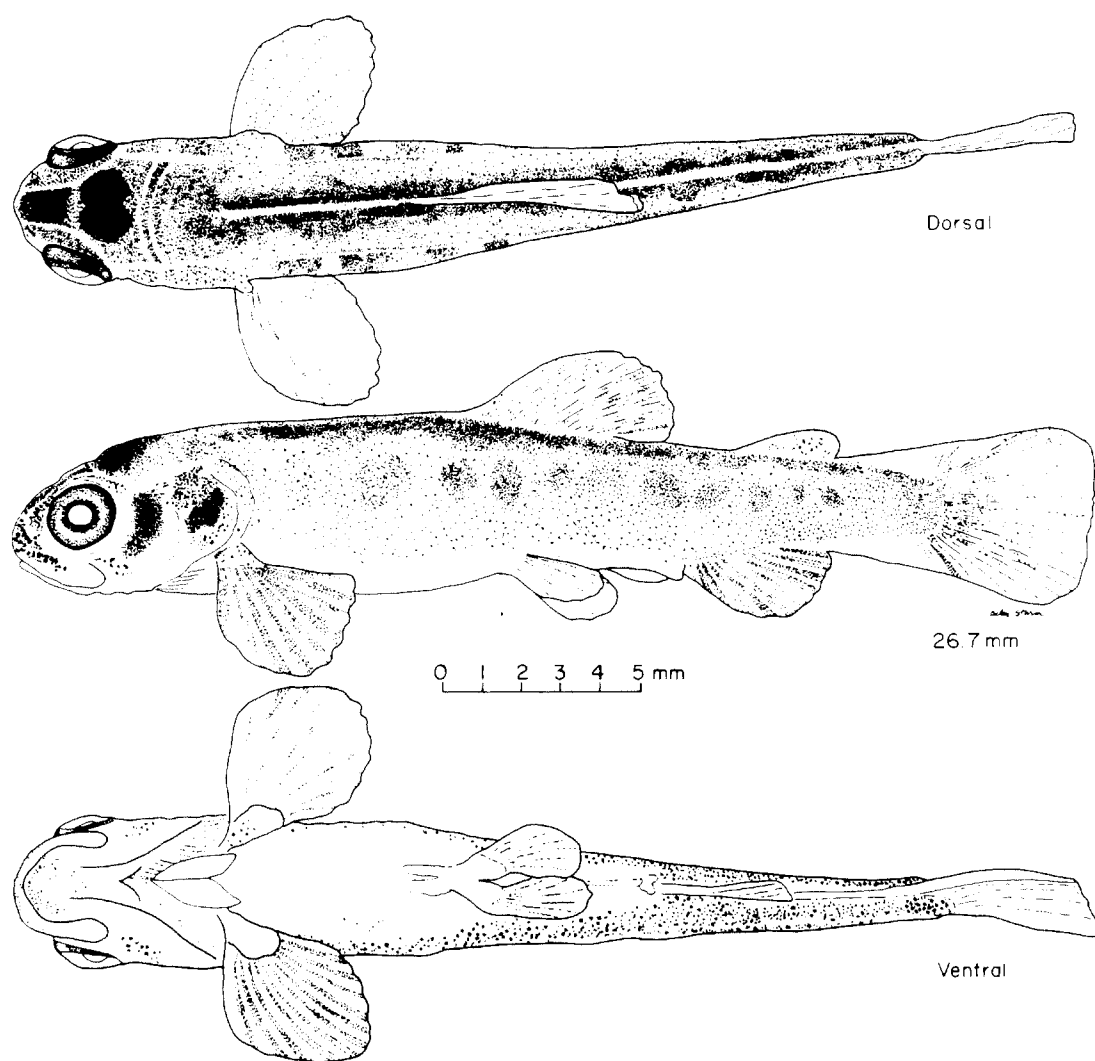


Figure 22. 26.7 mm Dolly Varden metalarva collected from the Tiekel River, Alaska.

adipose fin is now pigmented. Both large and small parr marks are present. There are 10-12 large parr marks, and on some specimens, numerous small parr marks on the lateral and dorsal surface.

The Juvenile Period

At 41 mm (Figure 23), the morphometry remains relatively unchanged. There are 20 principal caudal fin rays, 11 to 12 principal dorsal fin rays, 10 to 11 principal anal fin rays, 11 to 14 principal pectoral fin rays, and 9 pelvic fin rays. The 11-13 large parr marks are oval. Numerous small parr marks can be seen above the lateral line and on the dorsal surface.

Family Thymallidae

This family consists of four species of which only the Arctic grayling (Thymallus arcticus) is found in North America. Originally, the Arctic grayling was considered to be four separate species (T. signifer, T. montanus, T. tricolor, and T. ontariensis) (McPhail and Lindsey 1970, Scott and Crossman 1973). Now many authors consider these subspecies of T. arcticus.

Arctic Grayling

Arctic grayling are distinguished by a large and colorful dorsal fin. They are an extremely important sport fish in Alaska (Morrow 1980).

Distribution and Ecology

Range - Arctic grayling are found throughout Alaska, including St. Lawrence Island. They were introduced to many lakes in southeastern Alaska and on the Kenai Peninsula (Scott and Crossman 1973, Morrow 1980).

Habitat - Arctic grayling inhabit northern freshwater drainages including lakes and both bog-fed and spring-fed streams and rivers (Reed 1964).

Spawning

Location - Spawning occurs in clear water tributaries over various types of substrates including gravel riffles and in highway culverts (Reed 1964, Kratt

1981). Spawning can occur in turbid waters caused by spring flooding (Schallock 1966).

Nests - No nest is constructed. During spawning, the vibrations of the tails of both the male and female create a small depression in which the eggs settle. The eggs are buried in about 4 cm of gravel (Reed 1964, Tack 1971).

Season - Arctic grayling spawn in the spring as the ice is beginning to break up. Tack (1973) observed spawning in the Chena River in May.

Sexual Dimorphism - The dorsal and pelvic fins of the male are much longer than that of the female (McPhail and Lindsey 1970).

Age at Maturity - Arctic grayling mature at different ages depending on the river system. Armstrong (1986) summarized several studies on age at maturity. In interior Alaskan streams, most grayling mature between ages 4 and 6. On the North Slope, however, grayling generally mature between the ages of 6 and 9.

Fecundity - Arctic grayling in a river system near Tok produce between 4,200 and 7,400 eggs (Tack 1971). Schallock (1966) found egg counts between 1,700 and 12,350 for Chatanika River stock.

Eggs

Description - Just prior to hatching, Arctic grayling

eggs average 4.1 mm in diameter. The eggs are transparent with a pale yellow yolk. The embryo's eyes are darkly pigmented (this study).

Incubation Period - At 8°C, embryos hatch in 18 days. At 15°C, they hatch in 8 days (Wojcik 1955). Watling and Brown (1955) described the development from fertilization through hatching.

The Larval Period

Protolarval Phase - Newly hatched grayling average 11 mm (Figure 24). There are 54-58 total myomeres and 13-19 postanal myomeres. Morphometric measurements are given in Table 6. The large, round yolk sac is pale yellow with numerous oil globules. Larvae are densely pigmented with stellate melanophores on the dorsal surface. The pigmented pattern on the skull cap is oval-shaped. Two rows of melanophores parallel the dorsal finfold. Stellate melanophores lightly cover the lateral and ventral surfaces of the yolk sac. The pigmentation continues posteriorly just above the ventral finfold.

Mesolarval Phase - At 14 mm (Figure 25), the head length has increased to 18% TL and the predorsal length to 26% TL. Four to six caudal rays are visible, and the pelvic buds are apparent. The dorsal surface is again densely pigmented. The pattern on the skull cap is

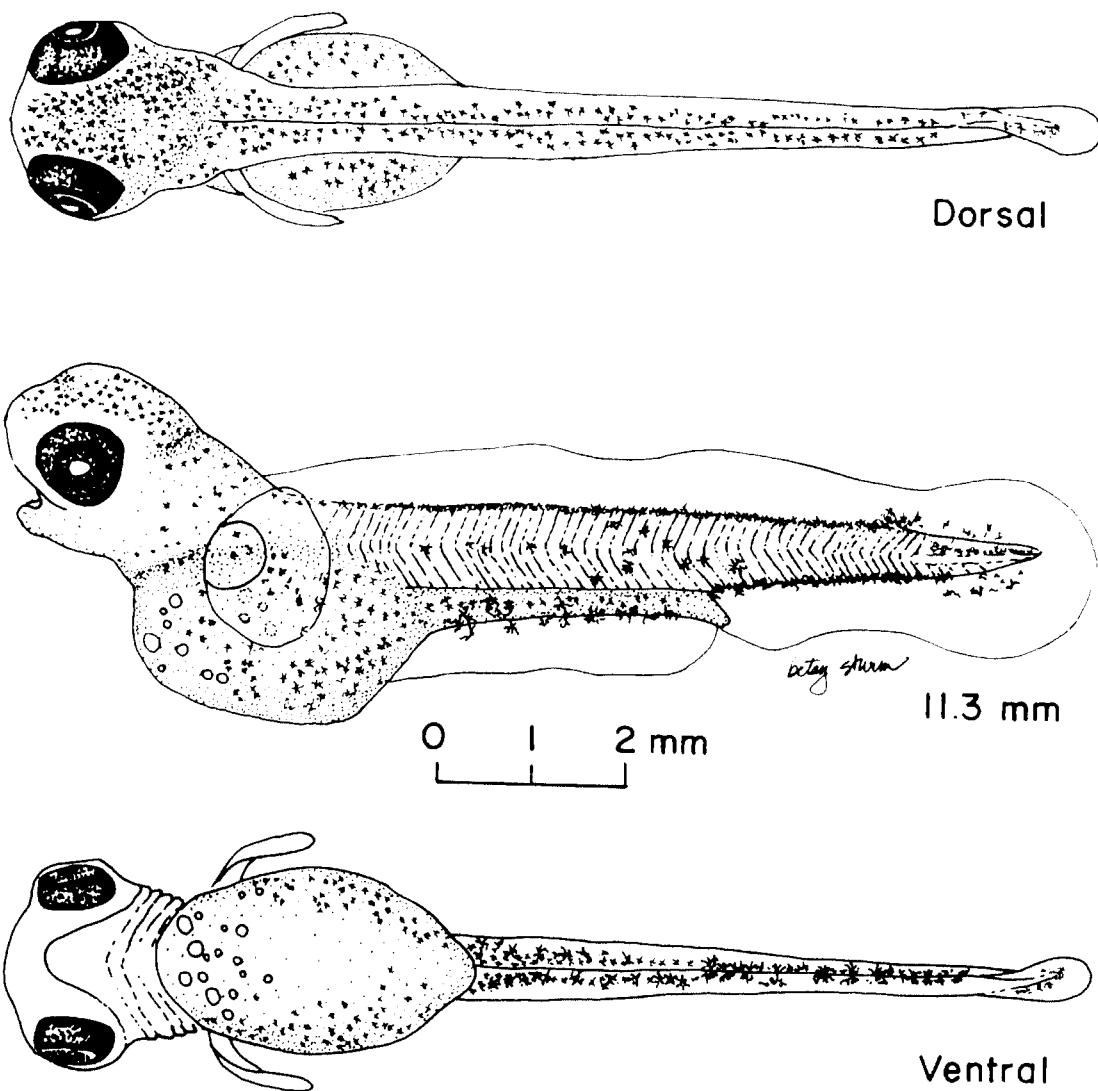


Figure 24. 11.3 mm newly hatched Arctic grayling protolarva reared in a hatchery.

Table 6. Selected morphometric characters measured as a percent of total length for the early life phases of Arctic grayling. See Table 2 for definitions of morphometric characters.

PR = protolarva, MS1 = early mesolarva

MS2 = late mesolarva, MT1 = early metalarva

MT2 = mid-metalarva, MT3 = late metalarva

JV = juvenile.

Morphometric Characters	<u>Life Phase</u>						
	PR	MS1	MS2	MT1	MT2	MT3	JV
n =	3	11	9	6	6	9	7
AS to:							
AE	2	3	3	3	4	4	3
PE - AE	8	7	8	8	8	7	7
OP1	18	21	22	21	23	20	19
OD	18	26	33	34	34	32	32
OP2	-	46	45	44	43	43	42
OA	66	68	68	67	65	65	65
SL	94	96	95	87	85	85	84

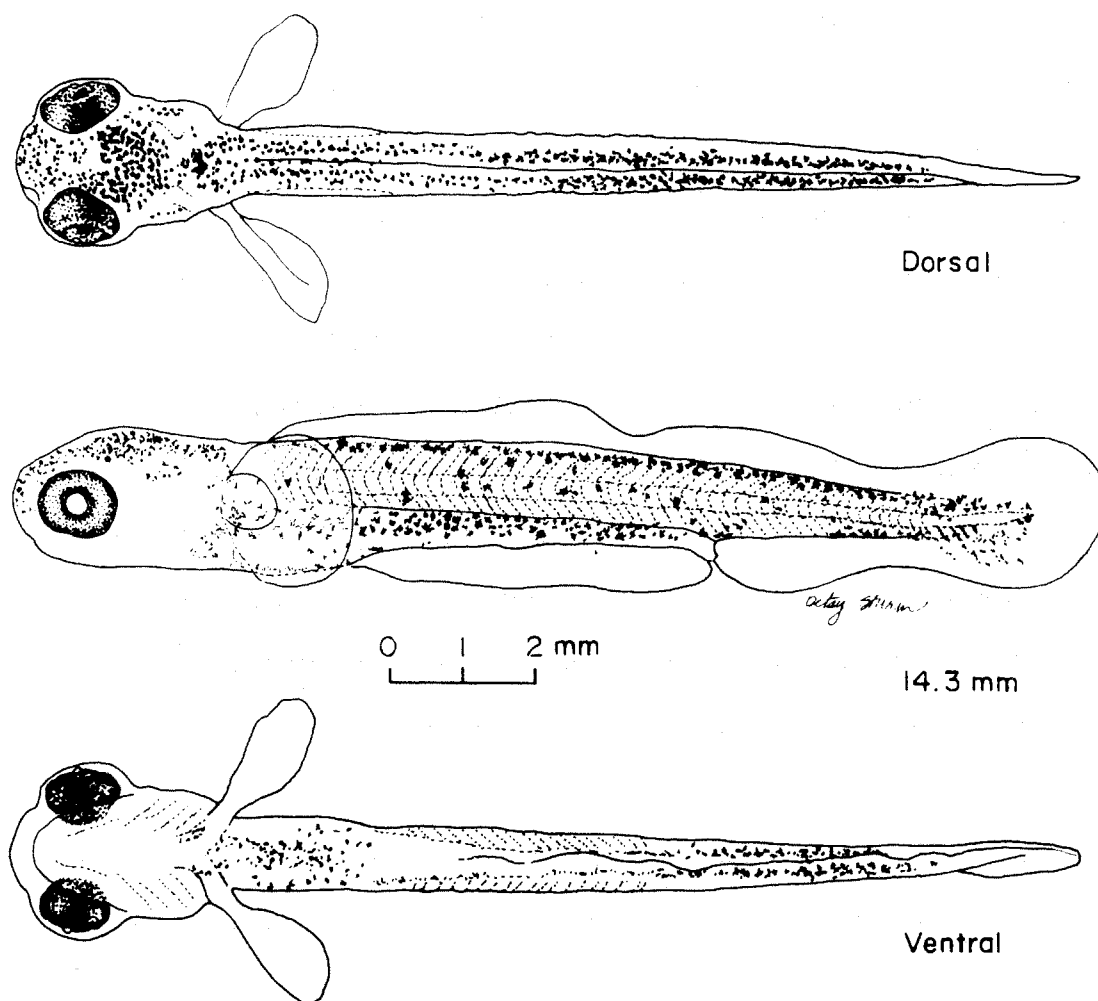


Figure 25. 14.3 mm Arctic grayling mesolarva reared in a hatchery.

prominent. The pigmentation pattern is similar to the protolarva except that now the gut wall, outlined by stellate melanophores, is visible.

At 16-17 mm (Figure 26), the predorsal length increases to 33% TL. There are 10 caudal fin rays, 9 to 10 anal fin rays, and 12 to 14 dorsal fin rays. The notochord is upturned to a 45 degree angle. Dense contracted melanophores can be seen on the dorsal surface. The lateral surface is dotted with small melanophores. Contracted melanophores line the gut wall. On the ventral surface, very small contracted melanophores can be seen on the belly.

At 21.3 mm (Figure 27), rays on the caudal fin have increased to 20 and on the dorsal to 15. Pigmentation on the lateral surface has increased overall.

Metalarval Phase - At 25 mm (Figure 28), the standard length has decreased to 88% TL. There are 19 principal caudal fin rays, 17-19 dorsal fin rays, and 12 anal fin rays. The skull cap pigmentation has changed from the round patch of the mesolarva to a heart-shaped pattern. A few contracted melanophores are apparent on the lateral surface. The dorsal and caudal fins are outlined with melanophores.

At 33 mm (Figure 29), the morphometry remains

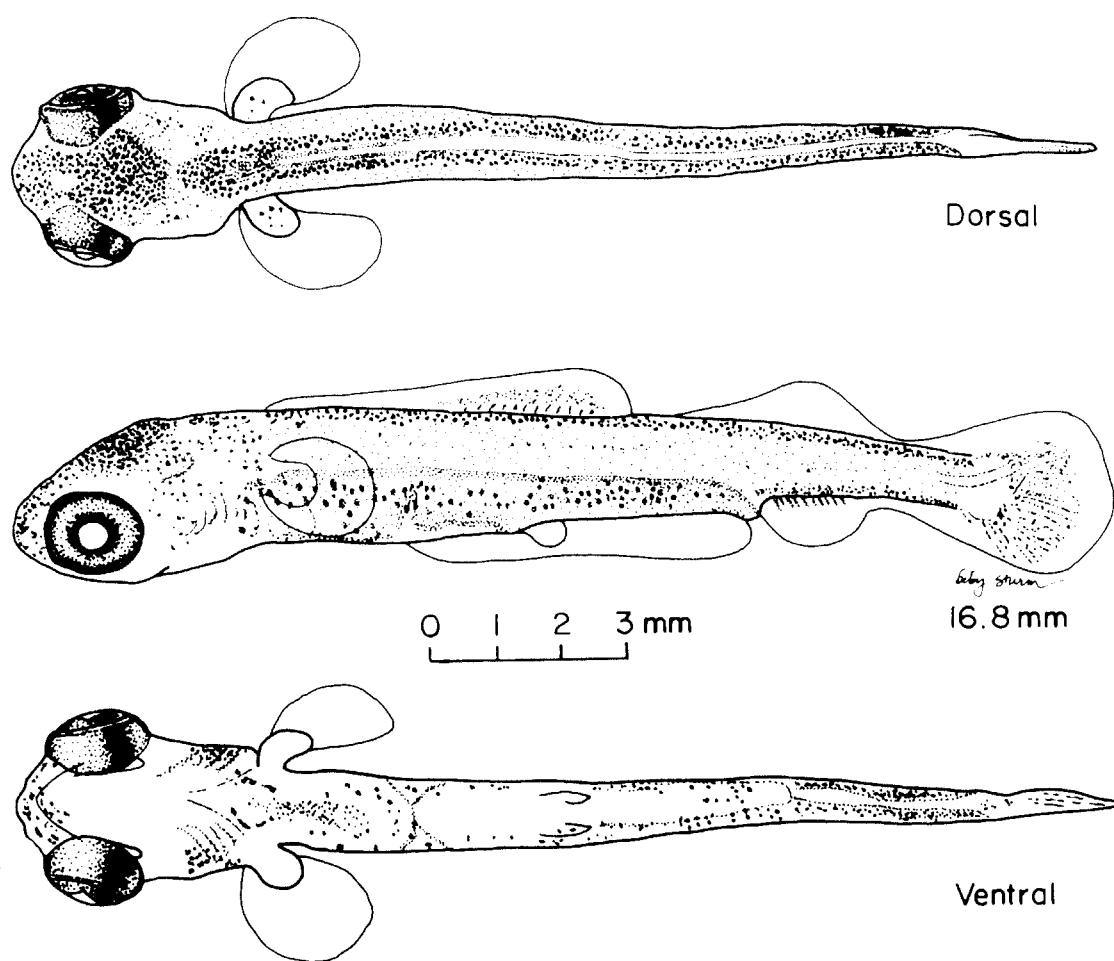


Figure 26. 16.8 mm Arctic grayling mesolarva reared in a hatchery.

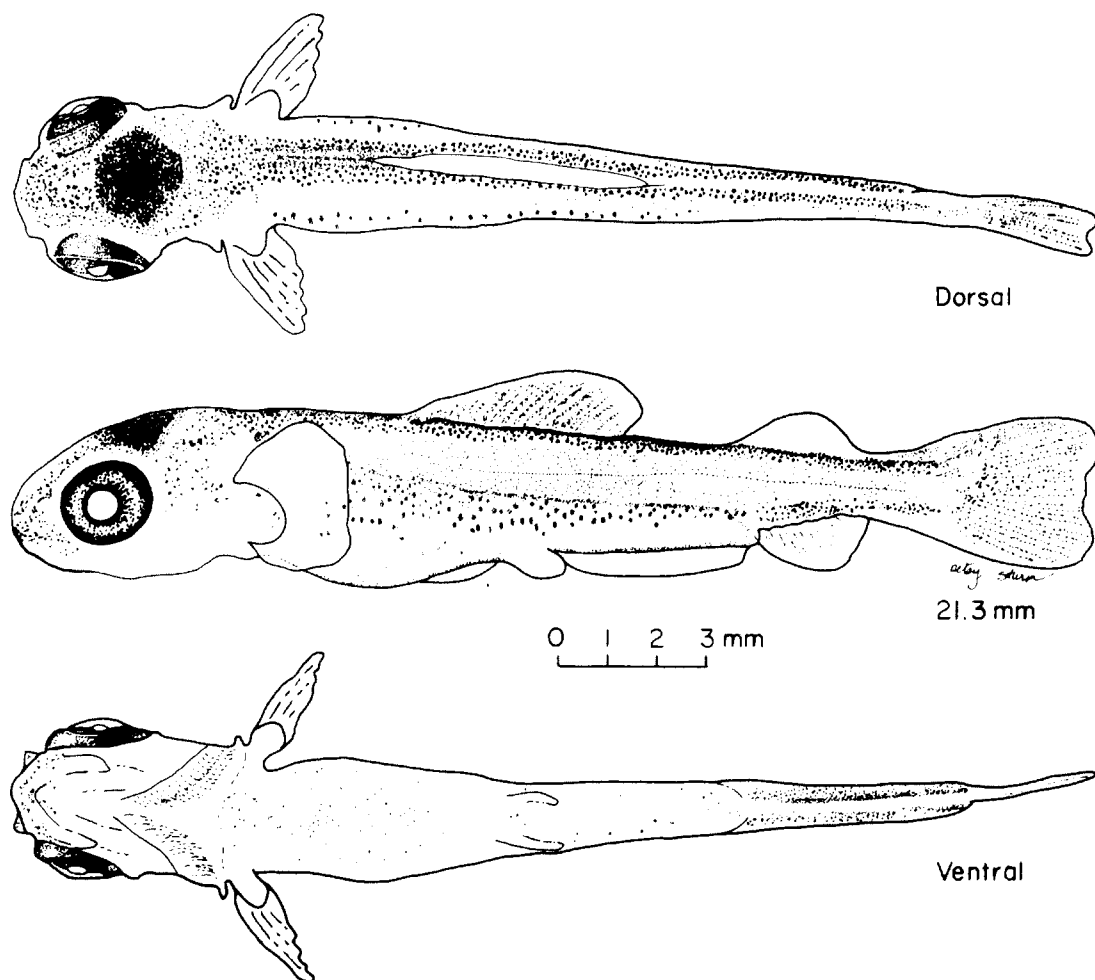


Figure 27. 21.3 mm Arctic grayling mesolarva reared in a hatchery.

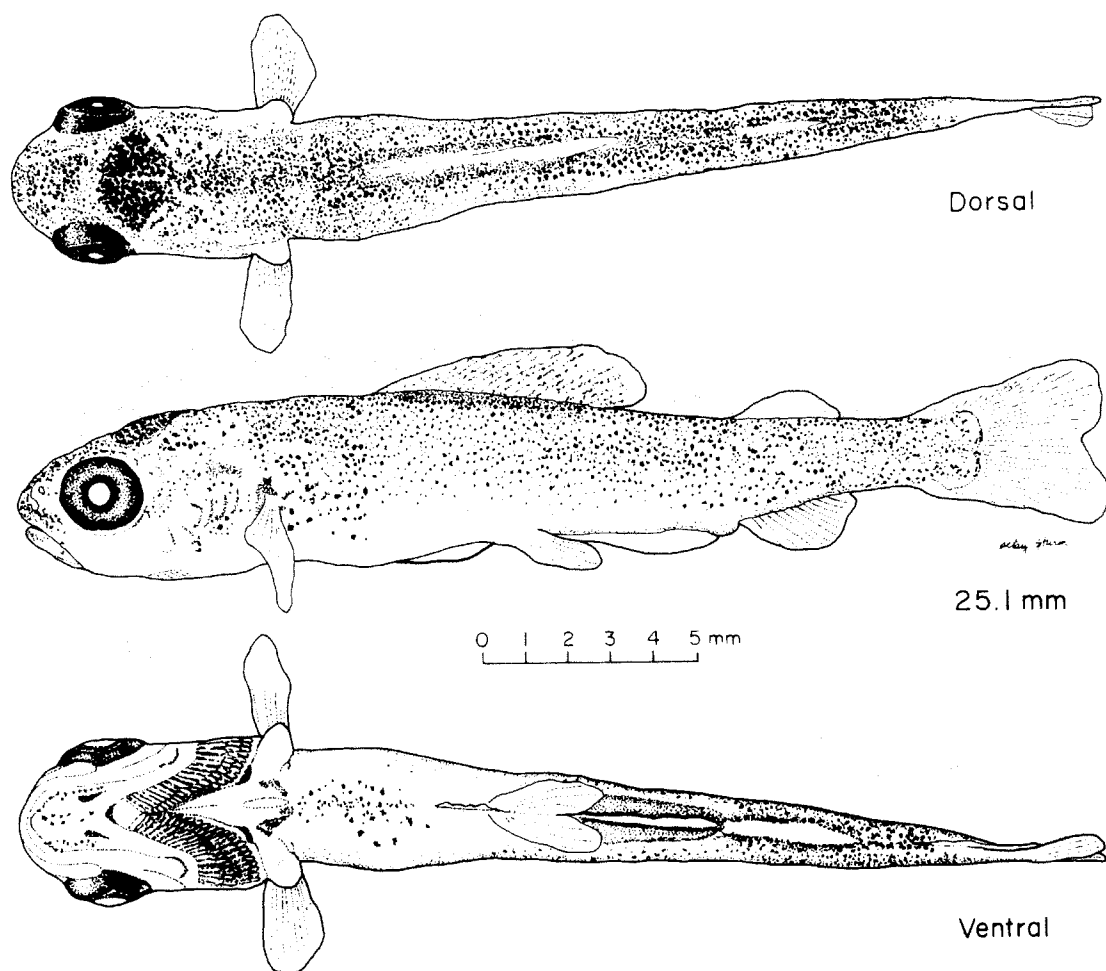


Figure 28. 25.1 mm Arctic grayling metalarva reared in a hatchery.

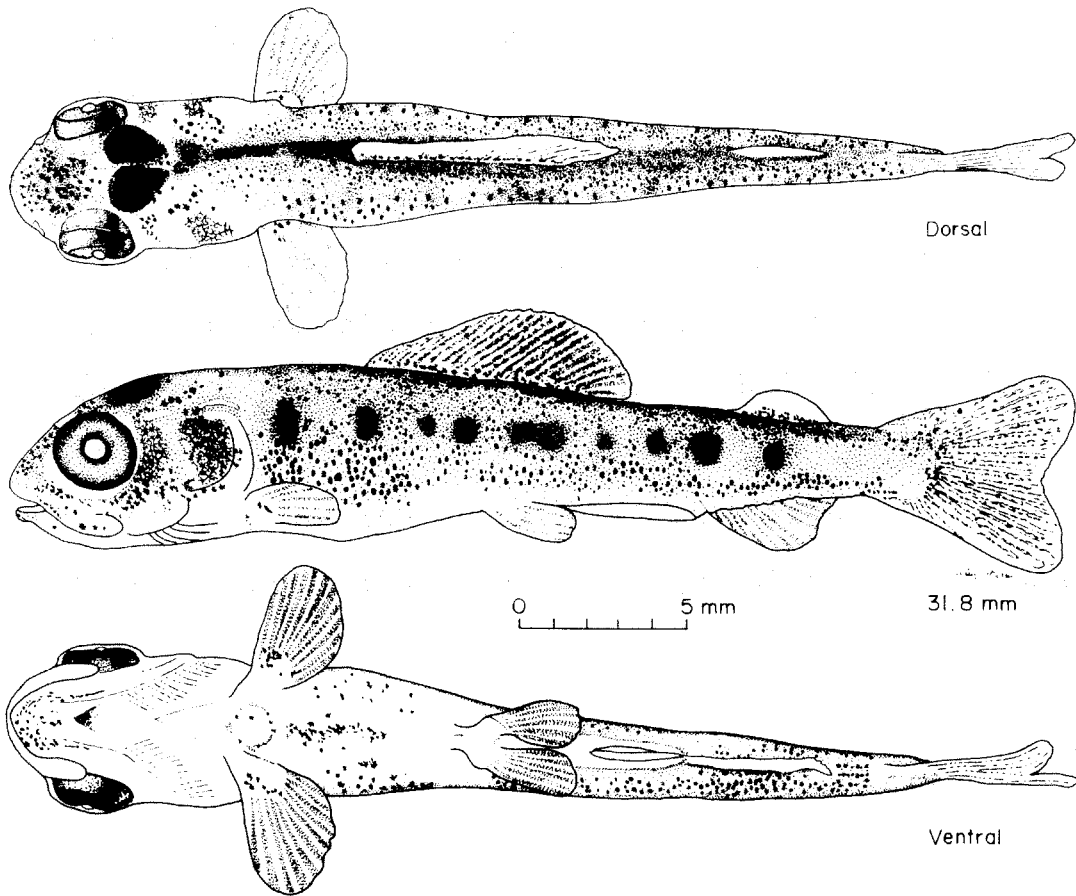


Figure 29. 31.8 mm wild caught Arctic grayling metalarva.

Family Percopsidae

The Percopsidae display characteristics of both trout and perch, hence the common name trout-perches. Like the trouts, these fish have an adipose fin and an abdominally placed pelvic fin. As with perches, there are one or two spines on the dorsal, anal, and pelvic fins, and the scales are ctenoid. The trout-perch is the only member of this family found in Alaska (Scott and Crossman 1973).

Trout-perch

The trout-perch is an important forage species for larger fishes (Morrow 1980).

Distribution and Ecology

Range - The trout-perch is rare in Alaskan waters but is found in the Porcupine and Yukon rivers (McPhail and Lindsey 1970).

Habitat - Trout-perch are typically found in quiet backwaters of large rivers (McPhail and Lindsey 1970) and deep waters of lakes (House and Wells 1973).

Spawning

Location - Spawning takes place in shallow, swift, streams and along sandy beaches of lakes (Langlois 1954, Magnuson and Smith 1963).

Nests - No nests are made. Eggs and milt are broadcast near the water surface. The fertilized eggs drift to

the bottom where they attach to a sandy substrate (Magnuson and Smith 1963).

Season - Spawning occurs in late spring and early summer (McPhail and Lindsey 1970).

Sexual Dimorphism - No obvious external differences occur between the sexes (McPhail and Lindsey 1970).

Age at Maturity - Males mature between their first and third year. Males mature at a younger age than females (Magnuson and Smith 1963, House and Wells 1973).

Fecundity - Lawler (1954) reported 210 to 730 eggs per female. House and Wells (1973) found the range to be 120 to 1,330 eggs per female.

Eggs

Description - The fertilized eggs are demersal and adhesive with a mean diameter of 1.9 mm. The mature eggs are yellowish (Magnuson and Smith 1963).

Incubation Period - The incubation period is 7 days at 20 to 23°C (Magnuson and Smith 1963).

The Larval Period

Protolarval Phase - Newly hatched larvae (Figures 44a and 44b) are about 6 mm long (Fish 1932, Magnuson and Smith 1963). There are 14 preanal and 18-20 postanal myomeres. The snout length is 4-6% TL, the eye diameter is 6-8% TL, the head length is 19-21% TL, and

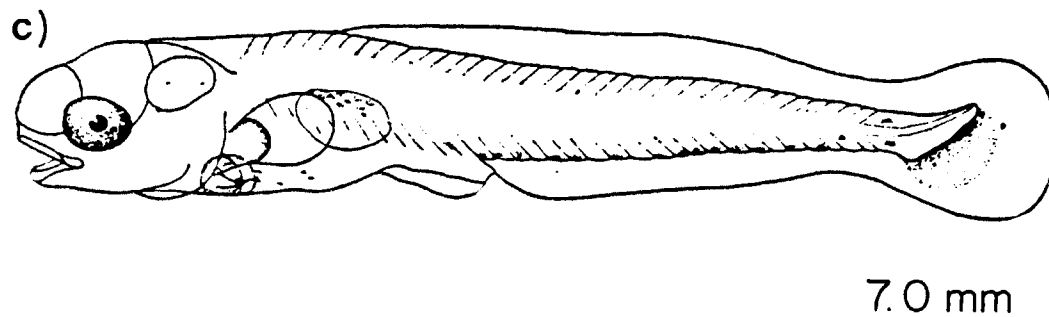
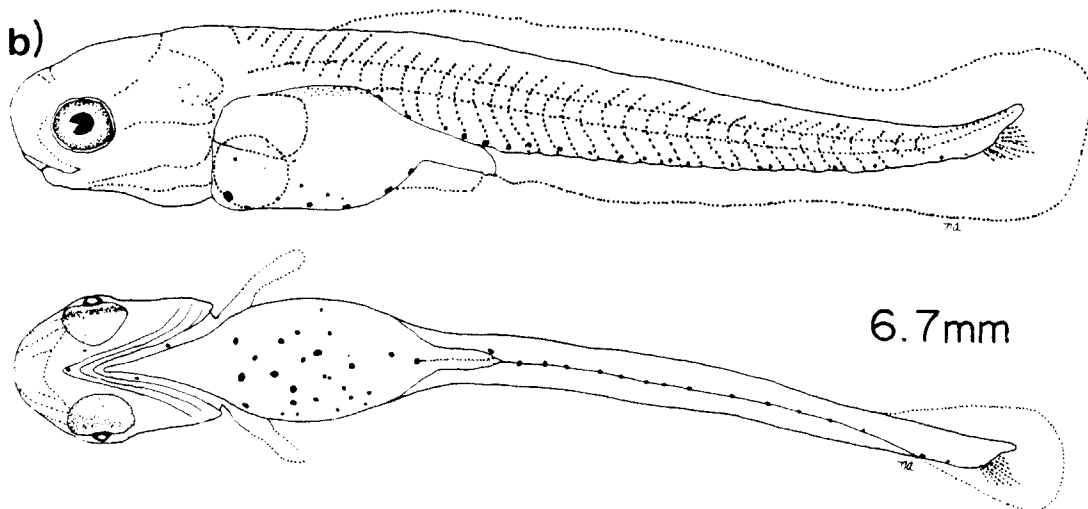
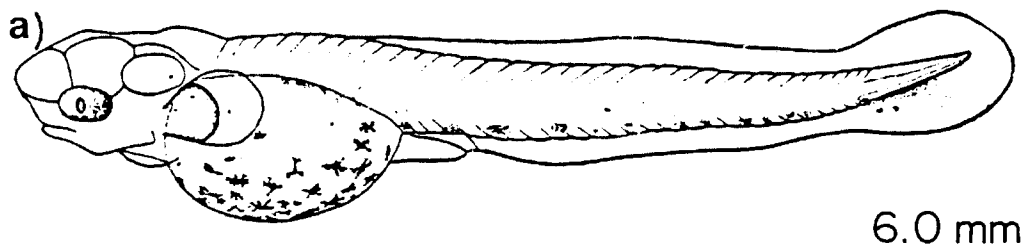


Figure 44. Larvae of trout-perch: a) newly hatched proto-larva (reproduced from Fish 1932) b) 6.7 mm proto-larva (reproduced from Auer 1982c, with permission) c) 7.0 mm mesolarva (reproduced from Fish 1932).

the preanal length is 44-45% TL (Auer 1982c). The snout is pointed and has a small, inferior mouth. The pectoral fins are present but unrayed and inconspicuous. Stellate melanophores occur on the ventral and lateral surface of the yolk sac and ventrally from the anus to the caudal fin (Fish 1932).

Mesolarval Phase - By the time larvae are 7 or 8 mm in length (Figures 44c and 45a), the snout length has increased to 6-7% TL, but other morphometric measurements remain similar. The yolk is absorbed, and the dorsal and anal fin rays are evident. Melanophores cover the dorsal surface of the swim bladder, with some pigmentation also found near the mouth and the dorsal surface of the head. A row of melanophores from the anus to the caudal fin remains from the protolarval phase. Some pigment is found near the base of the pectoral fin and just anterior to the stomach (Auer 1982c).

Metalarval Phase - Between 9 and 12 mm (Figure 45b), the snout length, head length, and preanal length increase to 8-9% TL, 23-24% TL, and 50-52% TL, respectively. The eye diameter is 7-8% TL and the standard length is 85% TL. The head is long with a pointed snout and teeth on both jaws of the mouth. The swim bladder is single-chambered. Eleven to 14 dorsal and

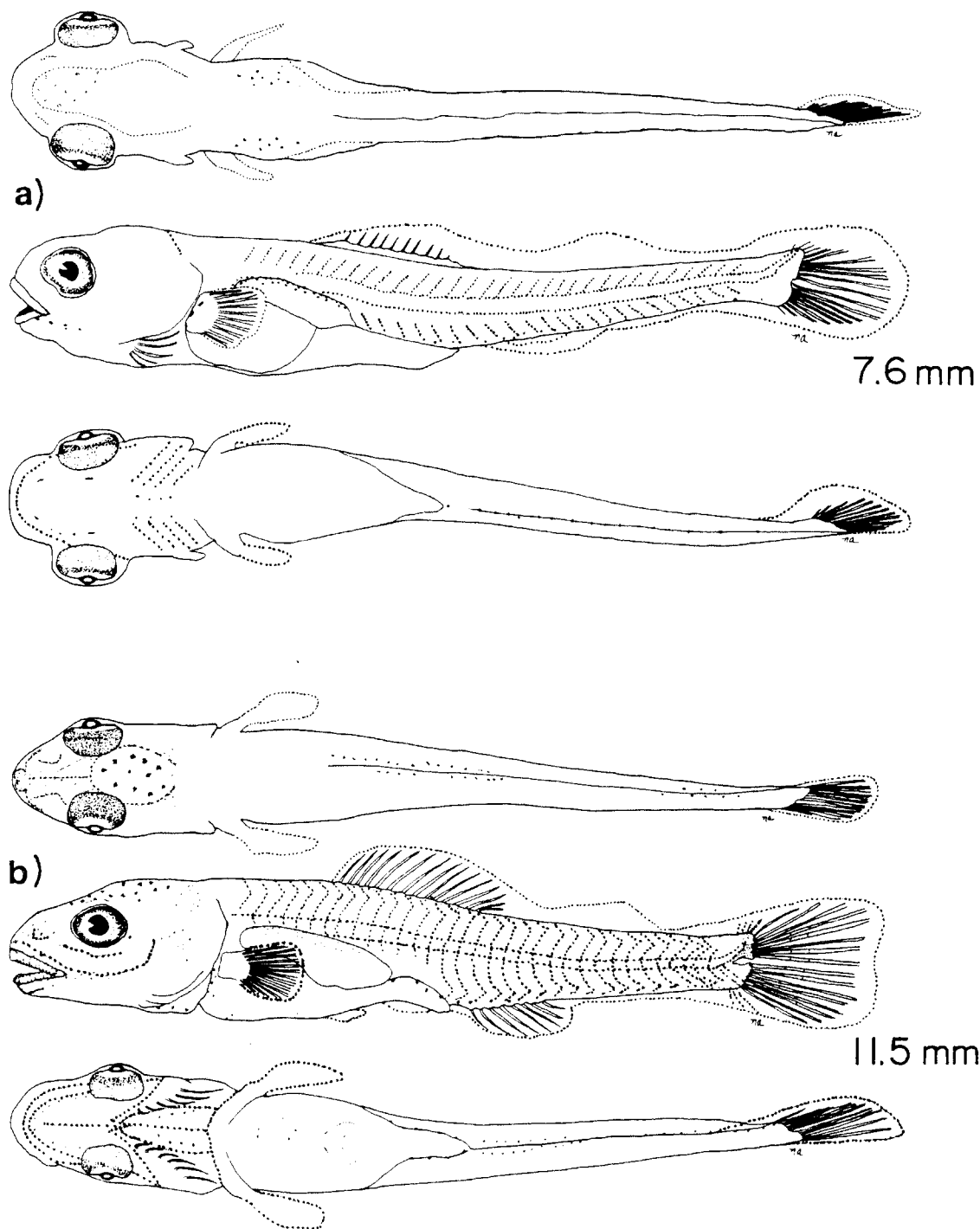


Figure 45. Larvae of trout-perch: a) 7.6 mm mesolarva showing the dorsal, lateral and ventral views. b) 11.5 mm metalarva showing the dorsal, lateral and ventral views (a and b reproduced from Auer 1982c, with permission).

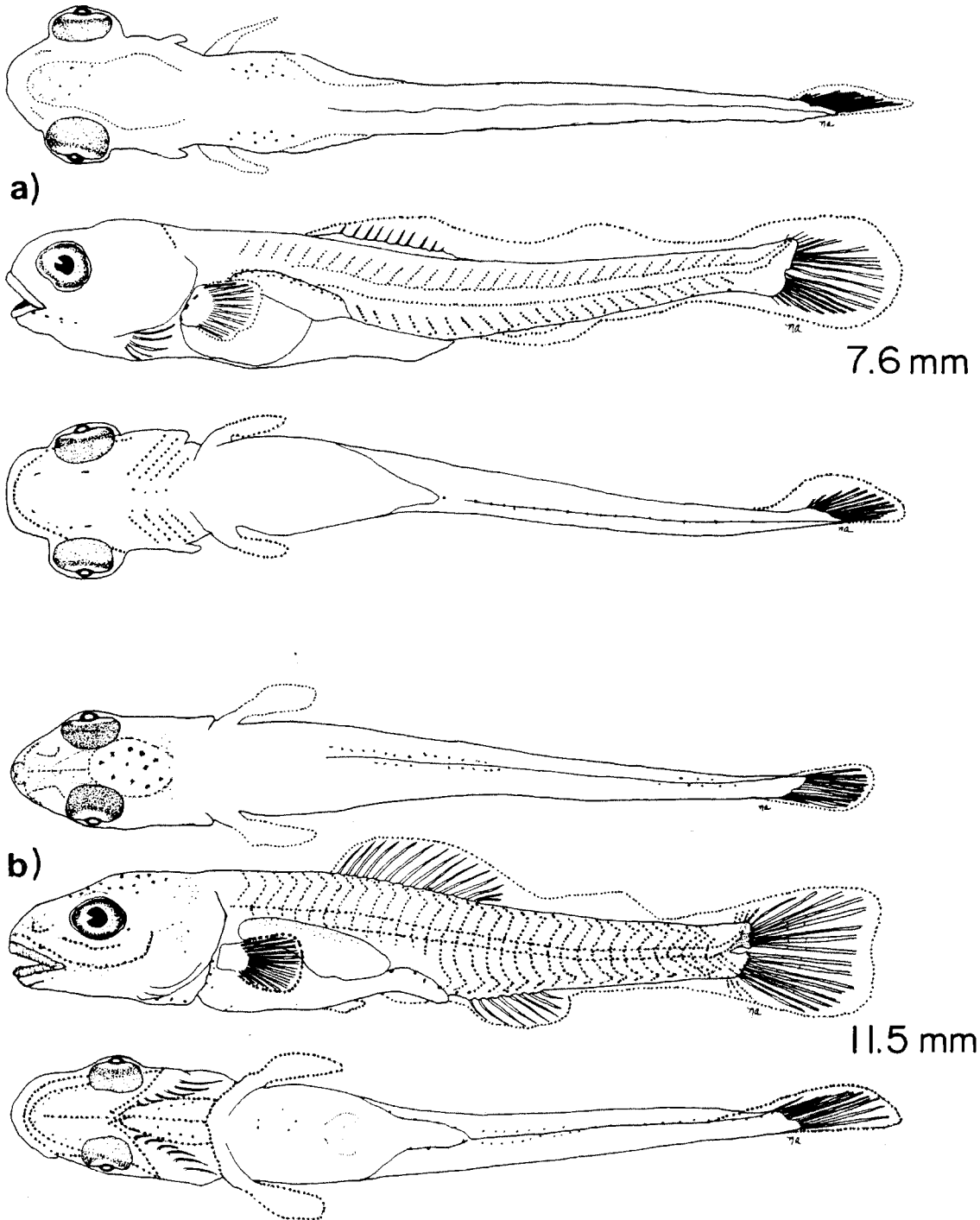


Figure 45. Larvae of trout-perch: a) 7.6 mm mesolarva showing the dorsal, lateral and ventral views. b) 11.5 mm metalarva showing the dorsal, lateral and ventral views (a and b reproduced from Auer 1982c, with permission).

8 anal fin rays are evident, and the pelvic buds are visible. Pigmentation can be found on the jaws and the dorsal surface of the head, with a few on the cheeks, below the jaws, and under the gills. The dorsal surface of the swim bladder is heavily pigmented. Melanophores are found on either side of the dorsal fin, on and at the base of the caudal fin, and ventrally from the anus to the caudal fin (Fish 1932, Auer 1982c).

The Juvenile Period

By 35-36 mm, the juvenile is fully scaled. The eye diameter is 7% TL, the head length is 25% TL, and the preanal and standard lengths have decreased to 48% and 79% TL, respectively. The mouth is small. The teeth on the premaxilla and mandible are also small. The caudal peduncle is long. Melanophores cover the entire body. Six lateral bands of pigmentation are visible (Fish 1932).

Family Gadidae

The codfishes, Gadidae, are recognized by their large heads, two or three dorsal fins, and one or two anal fins. Most codfishes are northern hemisphere, bottom-dwelling, marine fishes and are commercially important as a food source (Scott and Crossman 1973).

Burbot

The burbot is the only truly freshwater codfish. It is a nocturnal bottom-dwelling fish and is taken for subsistence and sport fishing in Alaska (Scott and Crossman 1973, Morrow 1980).

Distribution and Ecology

Range - Burbot are found in freshwater throughout Alaska including Kodiak Island (Scott and Crossman 1973).

Habitat - Burbot prefer cool waters of lakes and streams but will inhabit brackish and salt waters (Hubbs and Lagler 1958, Nikolskii 1961, Chen 1969). In the Tanana River, burbot occupy all types of habitat and remain fairly resident (Hallberg 1986).

Spawning

Location - Burbot spawn under the ice in mid-winter in shallow (<1.3 m), gravel-bottomed waters (Chen 1969, McPhail and Lindsey 1970).

Nests - No nests are built. Eggs settle on sand or gravel substrates (Bjorn 1939, Scott and Crossman 1973).

Season - Chen (1969) found spawning burbot in early February in the Tanana River. In Canada, burbot spawn from January through March (Scott and Crossman 1973).

Sexual Dimorphism - Males and females show no obvious external differences (McPhail and Lindsey 1970).

Age at Maturity - Chen (1969) suggested that burbot do not reach sexual maturity until age 6 or 7, but Hewson (1955) thought that maturity was associated more with size rather than age and found sexually mature burbot of age 2.

Fecundity - Burbot produce between 300,00 and 1,200,000 eggs (Chen 1969, Bailey 1972).

Eggs

Description - Eggs have one oil globule, are benthic, non-adhesive, and range in diameter from 0.7 to 1.1 mm (Nikolskii 1961, Chen 1969).

Incubation Period - The incubation period is 30 days at 6°C to 70 days at 1°C (Bjorn 1939, Muth 1973).

The Larval Period

Protolarval Phase - Newly hatched larvae are 3 to 4 mm in length (Muth 1973, Snyder 1979) (Figures 46a and 46b). The total myomere count varies from 55 to 65

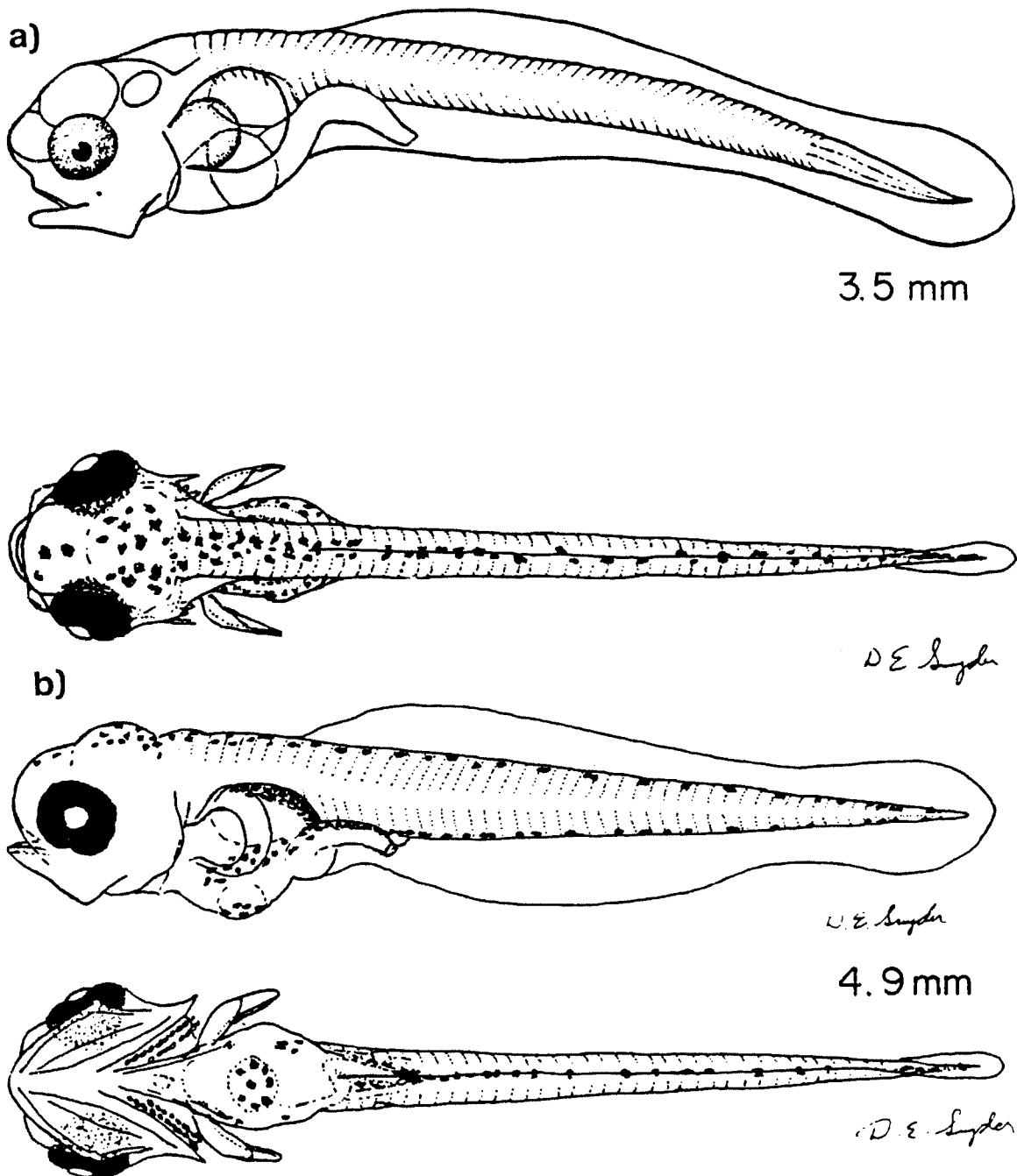
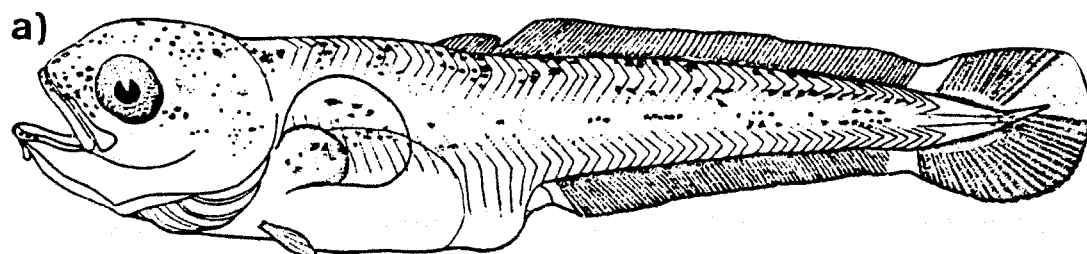


Figure 46. Larvae of the burbot: a) 3.5 mm newly hatched protolarva (reproduced from Fish 1932) b) 4.9 mm protolarva showing the dorsal, lateral and ventral views (b reproduced from Snyder 1979, with permission).

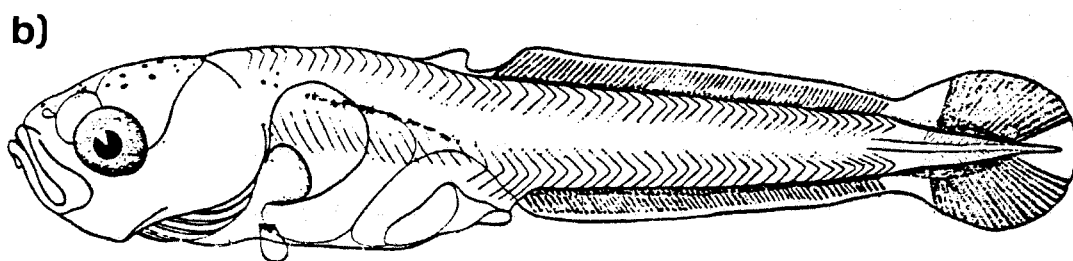
with 14 to 21 preanal myomeres. The eye diameter is 7-9% TL, the preanal length is 39-43% TL, and the standard length is 93-98% TL. The larval finfold originates between the 5th and 8th myomere and continues ventrally to below the vent region without breaking. The larva is colorless with a bulbous forehead, a terminal mouth, and a slightly protruding lower jaw. Eyes are pigmented. Melanophores are located laterally on the posterior portion of the swim bladder. Pigmentation over the entire dorsal surface and the lateral and ventral surface of the yolk sac appears to vary considerably depending on where the fish were collected (Fish 1932, Snyder 1979, Jude 1982).

Mesolarval Phase - At 10-11 mm (Figure 47a), the preanal length increases to 46% TL, and the standard length decreases markedly to 88% TL (Fish 1932). Fin rays are evident in this stage with 67 on the second dorsal fin and 64 on the anal fin. The barbel on the chin is visible. The pelvic buds are evident. Pigmentation is confined to a small area above the stomach region, the head, and the anterior portion of the notochord (Fish 1932).

Metalarval Phase - Between 14-19 mm (Figure 47b), the preanal and standard length increase to 50% and 90-94%



10.9 mm



14.0 mm

Figure 47. Larvae of the burbot: a) 10.9 mm mesolarva b) 14.0 mm mesolarva (a and b reproduced from Fish 1932).

TL, respectively. Fin ray differentiation is complete in the median and pelvic fins. The barbel is fully formed. Pigmentation on the head region has increased giving the appearance of a lateral band. The dorsal surface has numerous small groups of melanophores. Melanophores on the lateral line are also apparent and extend in a broken pattern to the tip of the notochord (Fish 1932).

The Juvenile Period

At 30-31 mm, pigmentation has increased on the head's dorsal and lateral surfaces. Irregular groups of melanophores on the dorsal and lateral surfaces of the body give a checkered effect. Some melanophores occur on all surfaces except the anal fin (Fish 1932).

Family Gasterosteidae

The major characteristic of the stickleback family is the presence of three or more spines preceeding the dorsal fin and one spine in front of the anal fin. The pelvic fin consists of one single spine with up to three soft rays. Sticklebacks are small fishes which are important as a forage species. They are found in shallow inshore areas of marine and fresh waters (Scott and Crossman 1973, Morrow 1980).

Ninespine stickleback

Ninespine sticklebacks are recognized by the presence of 7 to 12 free spines preceeding the dorsal fin. Ninespines, where abundant, are useful as dogfood (McPhail and Lindsey 1970, Scott and Crossman 1973, Morrow 1980).

Distribution and Ecology

Range - In Alaska, ninespine sticklebacks are found in lowland areas from Cook Inlet north along the coast to the Mackenzie River delta in Canada (McPhail and Lindsey 1970).

Habitat - In the marine environment, they are found in inshore areas and estuaries. In freshwaters, they are found in shallow bays of lakes, tundra pools, and streams (McPhail and Lindsey 1970).

Spawning

Location - Spawning sites of ninespine sticklebacks are usually associated with dense vegetation which provides the material for nests (McPhail and Lindsey 1970). Breeding stickleback nests are also found along barren, rocky lake shores with nests located in more exposed areas among rocks (McKenzie and Keenleyside (1970)).

Nests - Males usually build tunnel-shaped nests made of aquatic vegetation glued together by a secretion from the kidney. Nest sites are above the bottom of the river bed or constructed in organic bottom muds. Eggs are deposited in the nest and then guarded and fanned by the male (Nikolskii 1961, McKenzie and Keenleyside 1970, Griswold and Smith 1973).

Season - McKenzie and Keenleyside (1970) reported spawning in spring at water temperatures of 10-17°C.

Sexual Dimorphism - At spawning time males become jet black under the chin and along the ventral surface (McPhail and Lindsey 1970, McKenzie and Keenleyside 1970).

Age at Maturity - Ninespine sticklebacks achieve sexual maturity at about age 2 (Nikolskii 1961, Griswold and Smith 1973).

Fecundity - Fecundity ranges from 60-110 eggs per female with the number of eggs increasing with the

length of the female (Griswold and Smith (1973)).

Eggs

Description - Eggs range from 1.5 to 2.0 mm in diameter and contain a number of oil globules (Browne 1906, Griswold and Smith 1973).

Incubation Period - The incubation period is 5 days at 12°C (Griswold and Smith 1972).

The Larval Period

Protolarval Phase - Newly hatched ninespine sticklebacks are 5-6 mm long (Figures 48a and 48b) (Browne 1906, Griswold and Smith 1972). Total myomere count is 30 with 14 preanal myomeres. The head length is 21-22% TL, and the preanal length is 52-53% TL. The swim bladder is visible. The mouth is distinctly terminal. Melanophores cover the entire dorsal surface, and ventrally, a line of melanophores extends from the heart region to the anus. Lateral bands of melanophores extend from the heart region to the midgut area (Heufelder 1982a).

Mesolarval Phase - Between 7 and 9 mm (Figures 49 and 50a), the number of myomeres increases to 31-33. The head length is 20-24% TL, the preanal length is 51-58% TL, and the standard length is 96-99% TL. Four pairs of gill arches are visible under the opercle and all

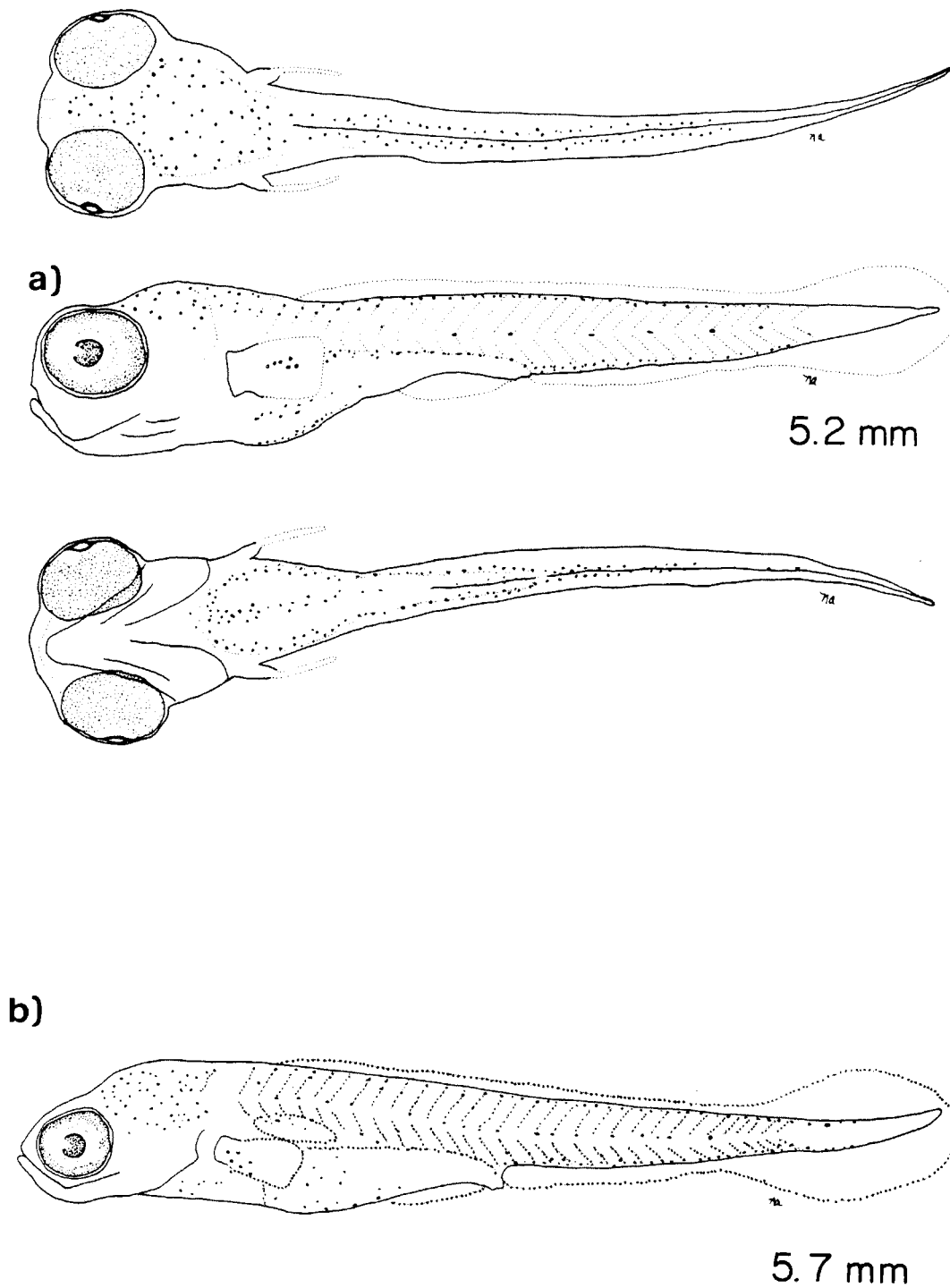


Figure 48. Larvae of the ninespine stickleback: a) 5.2 mm protolarva showing the dorsal, lateral, and ventral views b) 5.7 mm protolarva (reproduced from Auer 1982d, with permission).

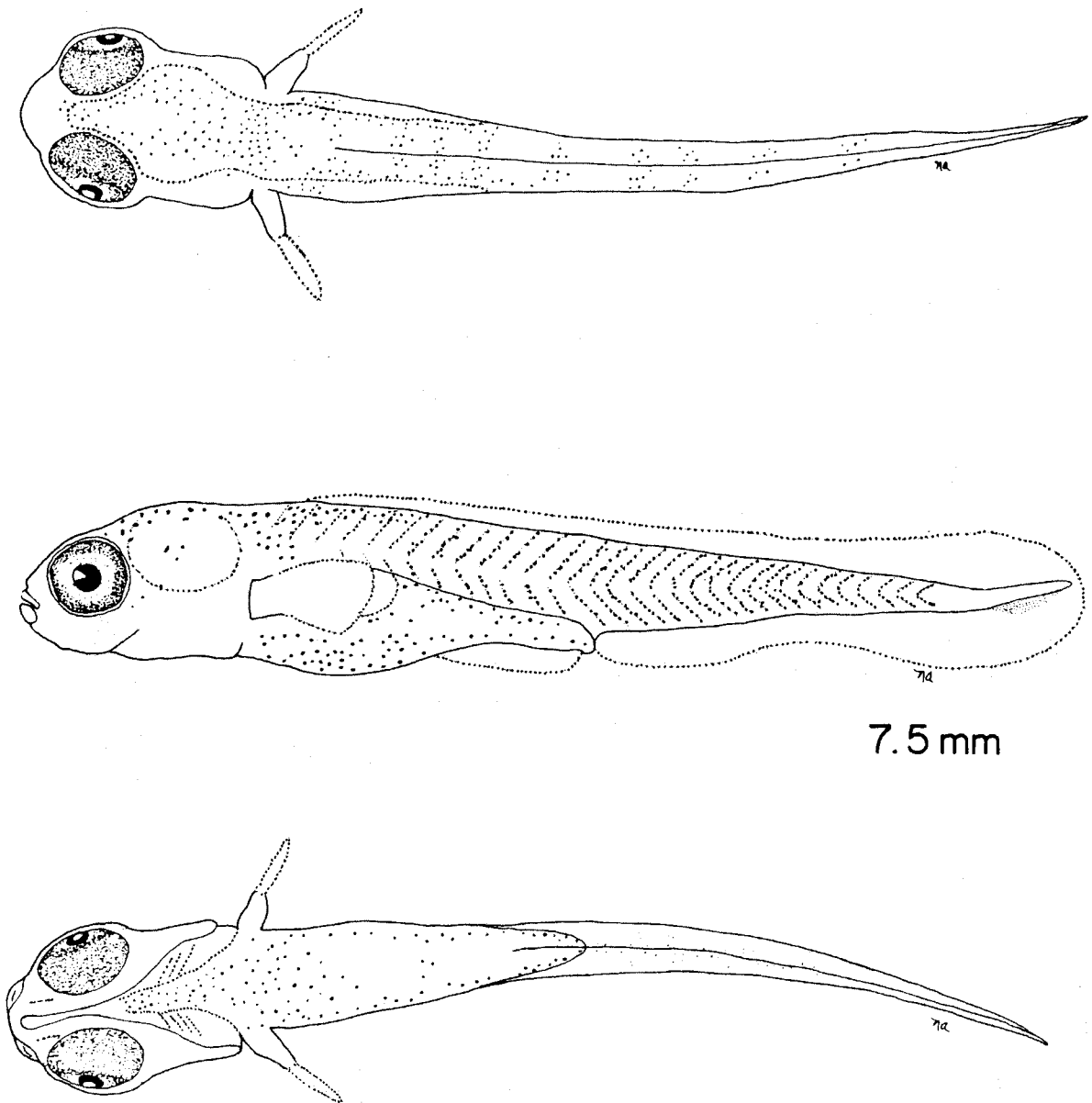


Figure 49. 7.5 mm ninespine stickleback protolarva showing the dorsal, lateral, and ventral views (reproduced from Auer 1982d, with permission).

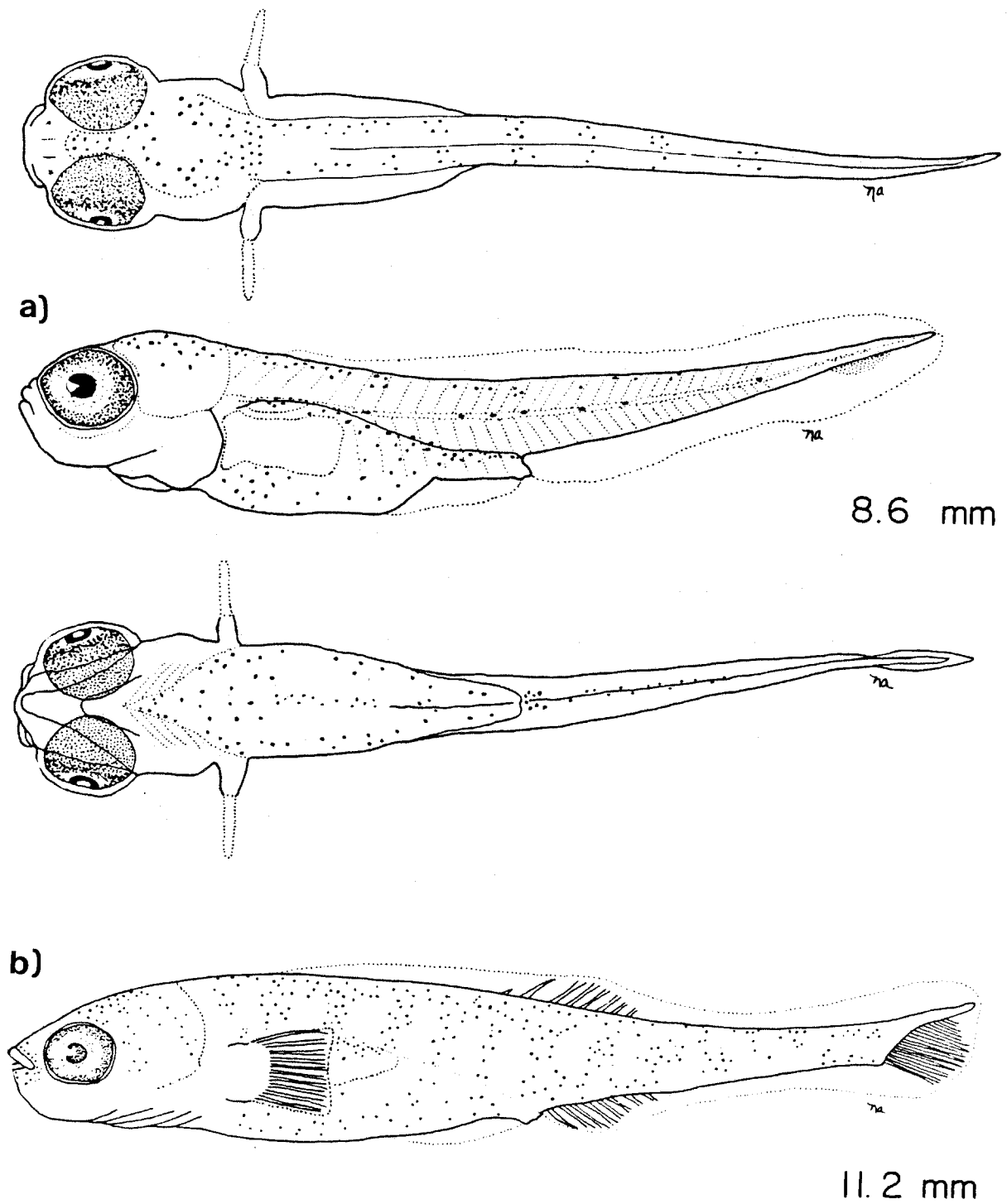


Figure 50. Larvae of the ninespine stickleback: a) 8.6 mm mesolarva showing the dorsal, lateral, and ventral views b) 11.2 mm mesolarva (reproduced from Auer 1982b, with permission).

three branchiostegal rays are present. The gut is developed. Caudal fin ray differentiation is evident. The yolk is absorbed. Pigmentation has increased in the head region, and bands of melanophores are evident on the dorsal surface of the main body. The ventral pigmentation is less distinct (Heufelder 1982a).

At 11-12 mm (Figure 50b), the myomere count remains the same. The head length is 20% TL and preanal length 52% TL. Pelvic buds have not yet formed, and the preanal finfold still exists. Fin-ray differentiation is apparent in the anal, caudal, dorsal, and pectoral fins. Pigmentation is similar to the early mesolarval phase.

Metalarval Phase - Information not reported.

The Juvenile Period

Information not reported.

Family Cottidae

The genus Cottus of the sculpin family, Cottidae, is circumpolar in freshwaters of the northern hemisphere. Three members of this genus are found in Alaskan freshwaters: slimy sculpin, Cottus cognatus; prickly sculpin, Cottus asper; and coastrange sculpin, Cottus aleuticus (Morrow 1980).

Slimy Sculpin

The slimy sculpin is an important forage fish that is widely distributed throughout Alaska (Morrow 1980).

Distribution and Ecology

Range - Slimy sculpin occur throughout Alaska including St. Lawrence Island in the Bering Sea, Nunivak Island, and the Kenai Peninsula (McPhail and Lindsey 1970, Scott and Crossman 1973, Morrow 1980).

Habitat - Slimy sculpin are typically found in cool, fast-flowing streams with rocky or gravelly bottoms. (McPhail and Lindsey 1970, Scott and Crossman 1973, Morrow 1980).

Spawning

Location - Slimy sculpin spawn in shallow running water under rocks or logs (Koster 1936).

Nests - Males choose nesting sites under rocks or logs, excavating a sandy bottom with strong swimming

movements and removing small gravel with their mouths. The eggs are deposited under the roof of a rock or log (Koster 1936).

Season - Spawning occurs shortly after breakup (Koster 1936, Van Vliet 1964).

Sexual Dimorphism - Males are dark brown to black during the spawning season. A bright orange margin outlines the first dorsal fin (Van Vliet 1964). The genital papilla is twice as long in males as in females (Koster 1936).

Age at Maturity - Craig and Wells (1976) determined maturity began at age 3 (minimum length 65-75 mm) in the Chandalar River, Alaska. In milder climates, slimy sculpin mature as early as age 1, though the minimum size limit for maturity remains about 70 mm (Van Vliet 1964).

Fecundity - Fecundity for the Chandalar River population ranges between 60 and 340 (Craig and Wells 1976).

Eggs

Description - Eggs are demersal, adhesive, and slightly oblong with a mean diameter of 2.3 mm. The yolk is pale yellow (Koster 1936, Van Vliet 1964).

Incubation Period - The incubation period is 28 to 29 days at 8-18°C (Van Vliet 1964).

The Larval Period

Protolarval Phase - Newly hatched slimy sculpin are 5-6 mm long (Figure 51a). Total myomere count is 32 with 9-11 preanal myomeres. Morphometric measurements are found in Table 8. A newly hatched sculpin has a large, spherical yolk sac with one large oil globule in the anterior portion. Sometimes smaller oil globules are nearby. The mouth is functional. The pectoral fins are present and about 0.6 mm in length. The notochord is slightly upturned. Pelvic fin buds and median fins are not present nor is pigmentation except for the black eyes. Several hours after hatching, melanophores on the dorsal surface of the yolk sac and midventral surface near the caudal fin appear (Koster 1936, Heufelder 1982b, this study).

Mesolarval Phase - Between 6 and 7.5 mm (Figure 51b and 52), the total myomere count is 30 with 11 preanal myomeres. Morphometric measurements are similar except for a noticeable decrease in the standard length. Pelvic buds may become evident at about 7 mm. Rays have formed in the pectoral and caudal fins with fin ray differentiation just evident in the dorsal and anal fins. Pigmentation in the form of stellate melanophores increase on the head and dorsal surface of the yolk sac. The notochord is upturned to a 45 degree

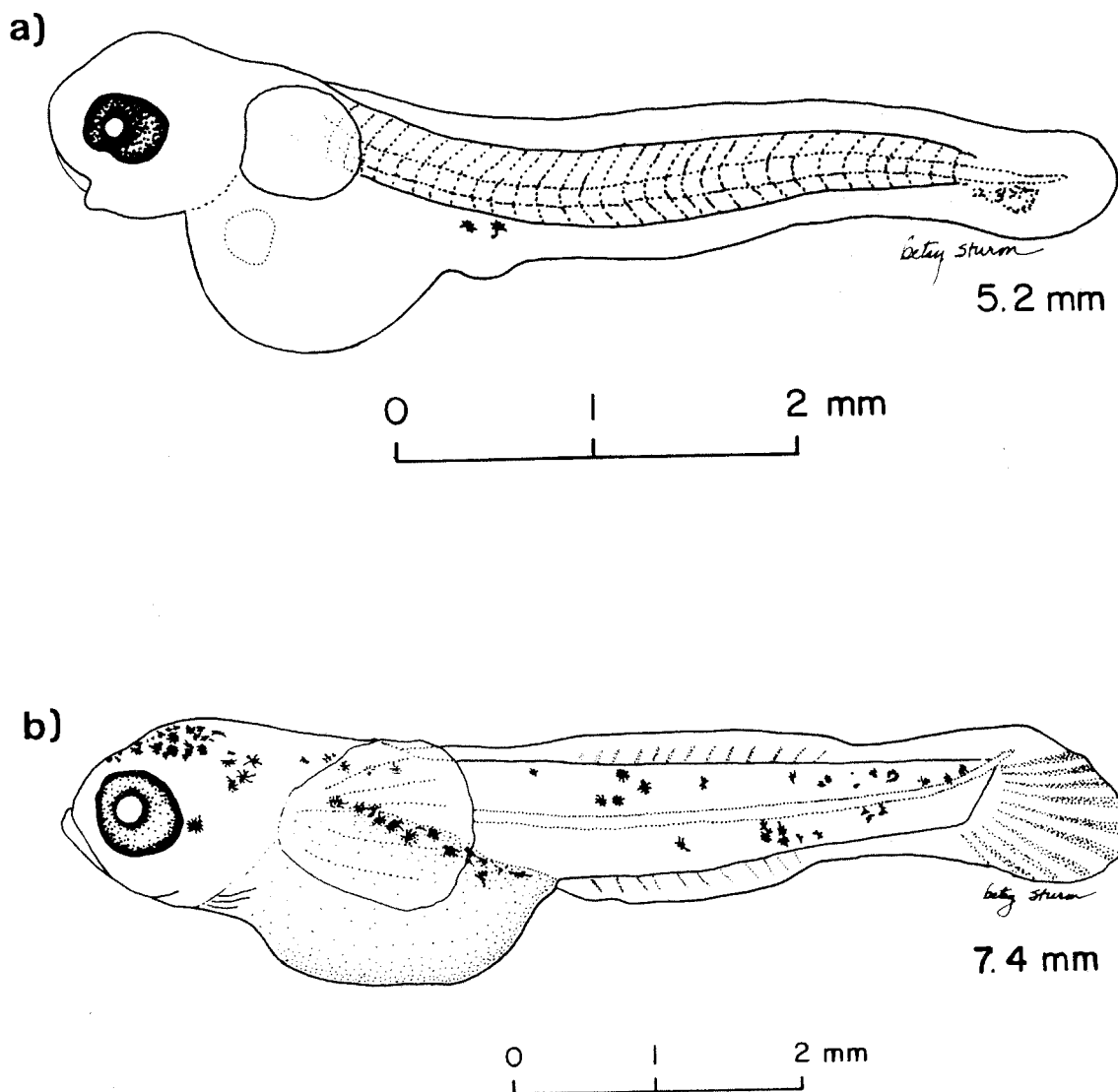


Figure 51. Larvae of the slimy sculpin reared in the UAF laboratory: a) 5.2 mm recently hatched protolarva
b) 7.4 mm mesolarva.

Table 8. Selected morphometric characters measured as a percent of total length for the early life phases of slimy sculpin. See Table 2 for definitions of morphometric characters.

PR = protolarva, MS = mesolarva,
 MT1= early metalarva, MT2 = late metalarva,
 JV = juvenile.

Morphometric Characters	<u>Life Phase</u>				
	PR	MS	MT1	MT2	JV
n =	2	6	10	7	7
AS to:					
AE	4	2	3	3	3
PE - AE	6	6	6	7	6
OP1	18	19	19	21	20
OD	26	24	25	23	25
OP2	-	-	19	22	21
OA	48	47	42	41	44
SL	91	86	81	79	81

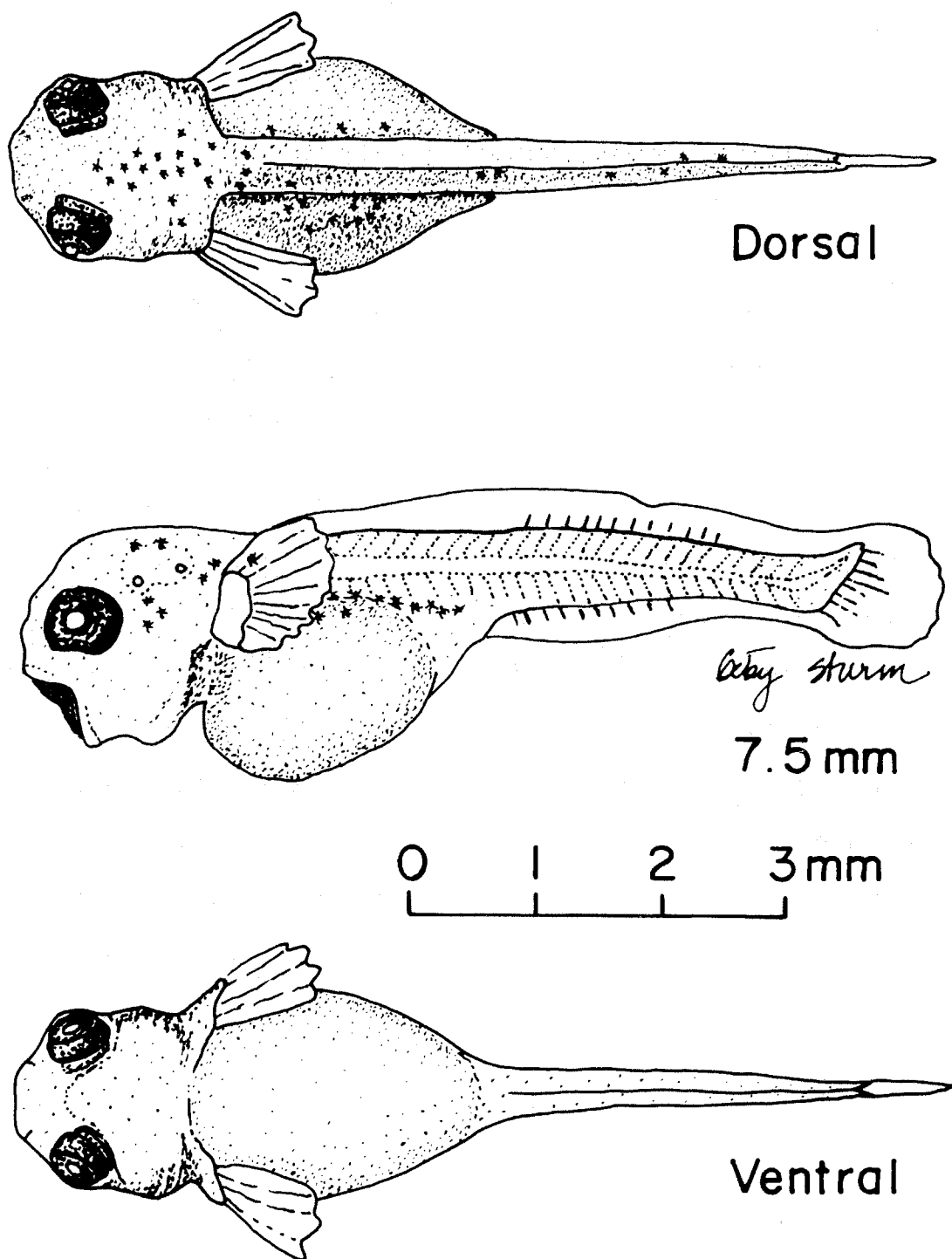


Figure 52. 7.5 mm slimy sculpin mesolarva reared in the UAF laboratory.

angle (Koster 1936, Heufelder 1982b, this study).

Metalarval Phase - Between 7.5 and 9 mm (Figure 53), the preanal and standard lengths have decreased to 42% TL and 81% TL, respectively. The yolk is almost fully absorbed. The first dorsal has 7 spines, the second dorsal 16 rays, the anal 11 rays, and the pectorals 13 rays. Lateral bands of pigmentation appear at about 7.5 mm (Heufelder and Auer 1980, this study).

The Juvenile Period

At 11 mm (Figure 54), total myomeres vary between 28 and 31 with 9-12 preanal myomeres. Morphometrics remain similar to the metalarval phase. Small prickles may occur in a patch posterior to the pectoral fins. The lateral banding increases in intensity, with an increase in density of melanophores over the head and dorsal surface (Heufelder and Auer 1980, Heufelder 1982b, this study).

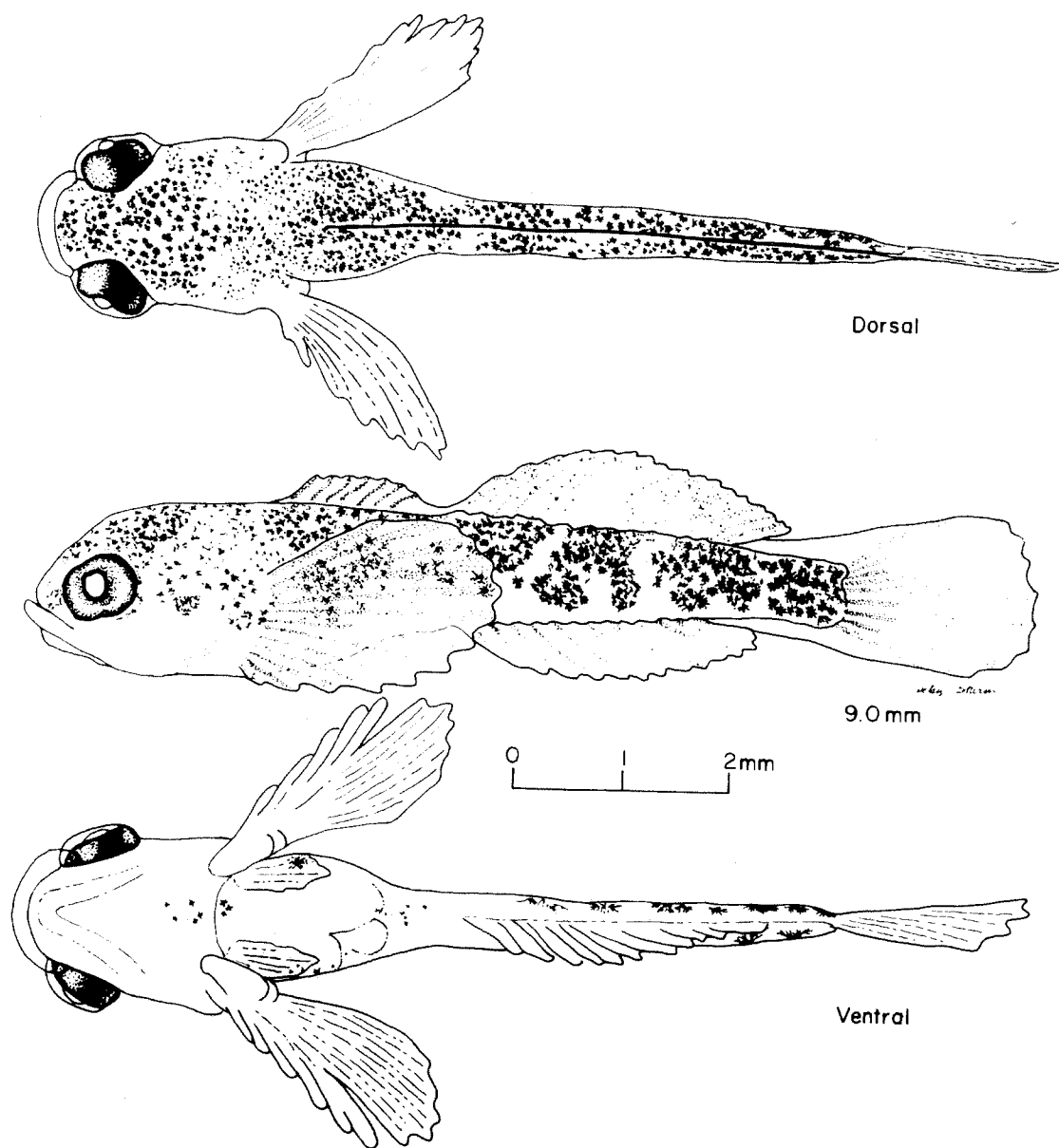


Figure 53. 9.0 mm slimy sculpin metalarva reared in the UAF laboratory.

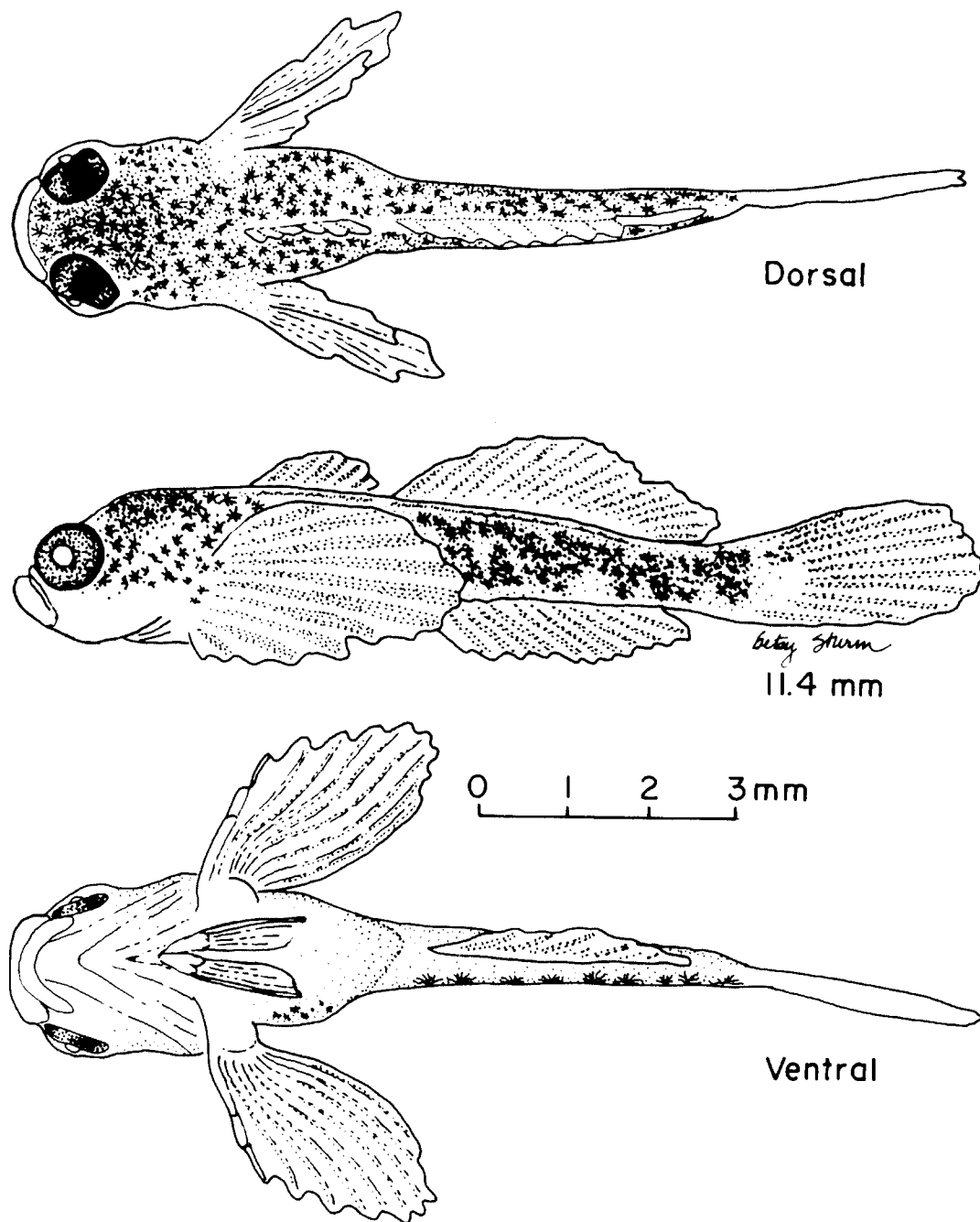


Figure 54. 11.4 mm slimy sculpin juvenile reared in the UAF laboratory.

Prickly Sculpin

Prickly sculpin exhibit two genetically distinct forms: an inland form and a coastal form. The inland form exhibits extensive squamation or prickling and remains in freshwaters to spawn. The catadromous coastal form has little or no squamation (prickling) and spawns in brackish water (Krejsa 1967a).

Distribution and Ecology

Range - In Alaska, prickly sculpin are found in coastal streams as far north as Seward and as far as 300 miles inland (Krejsa 1967a).

Habitat - Both forms inhabit pools and calm waters in clear coastal rivers and streams, avoiding areas of high current velocities (Krejsa 1967a).

Spawning

Location - The coastal form moves downstream to spawn in brackish waters of the estuary. The inland form exhibits local migrations to freshwater lakes or inlet streams of lakes (Krejsa 1967b).

Nests - Prior to spawning, males select nesting sites under large, flat rocks. Eggs are laid in a jelly-like cluster on the roof of the nest. After spawning, the male guards and fans the eggs until they hatch (Krejsa 1967b, Ringstad 1974).

Season - Spawning occurs in late July in the northern part of the range in water temperatures of 8-13°C (Krejisa 1967b).

Sexual dimorphism - Spawning males are darker than females. The genital papilla is long and v-shaped in males whereas in females it is short and round (McPhail and Lindsey 1970).

Age at Maturity - Patten (1971) found that prickly sculpin inhabiting streams in Washington and Oregon spawned at age 3.

Fecundity - Fecundity varies from 280 to 7,000 eggs, with egg number increasing with body length (Krejisa 1967b, Millikan 1968, Patten 1971).

Eggs

Description - Eggs are a translucent creamy yellow and slightly more than 1 mm in diameter (Millikan 1968).

Incubation Period - The incubation period is 15-20 days at 10-12°C (Krejisa 1967b, Mason and Machidori 1976).

The Larval Period

Protolarval phase - Larvae hatch at about 5 mm and are lightly pigmented (Richardson and Washington 1980) (Figure 55a). There are 35-38 total myomeres with 25-26 postanal myomeres (Stein 1972). Melanophores sparsely cover the dorsal surface of the gut and line

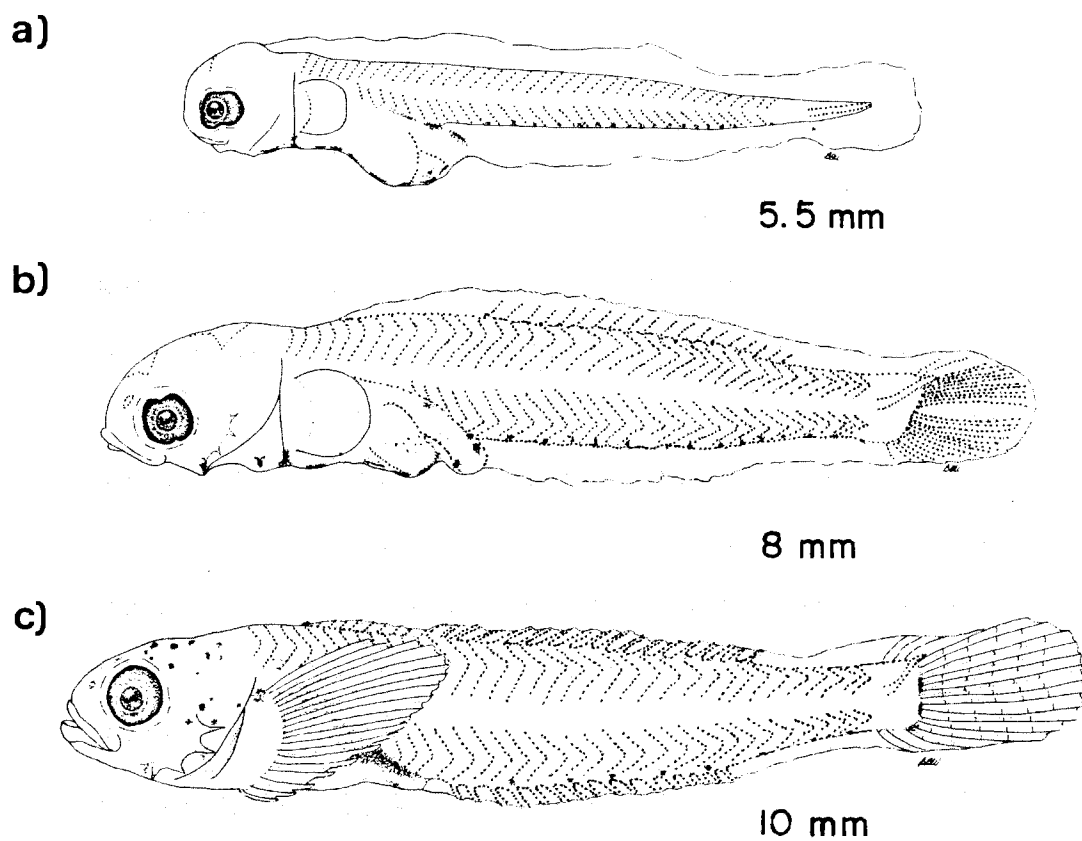


Figure 55. Larvae of the prickly sculpin: a) protolarva b) mesolarva c) metalarva (reproduced from Richardson and Washington 1980).

the ventral margin of the abdominal cavity and throat. Snout to vent length is about 40-46% TL. The body depth at the pectoral fin base is less than 20% TL (Richardson and Washington 1980). Six to 10 days after hatching, mouth parts are functional (Mason and Machidori 1976).

Mesolarval Phase - At about 8 mm (Figure 55b), four pronounced spines develop on the preopercular margin. Caudal and dorsal fin rays are evident (Richardson and Washington 1980). Lobes of the fore-, mid-, and hind-brain are evident. The notochord is upturned. The preanal myomeres range from 10-13 with 24-28 postanal myomeres. The yolk sac is completely absorbed (Stein 1972).

Metalarval phase - At about 10 mm (Figure 55c), melanophores increase in the head region, base of the pectoral fin, over the gut, and along the base of the caudal fin. Nine dorsal fin spines, 18 dorsal fin rays, 16 anal fin rays, 19 pectoral fin rays, and 4 preopercular spines are visible. Pelvic spines and rays are not yet evident (Richardson and Washington 1980).

The Juvenile Period

Thirty to thirty-five days after hatching, the young sculpins, which were pelagic, adopt a benthic habitat (Mason and Machidori 1976). The pelvic fins

contain 4 rays and 1 spine. Preanal myomeres are 13-14 and postanal 23-25 (Stein 1972).

Coastrange Sculpin

Coastrange sculpin are small and often found inhabiting areas peripheral to prickly sculpin populations (Ringstad 1974).

Distribution and Ecology

Range - Coastrange sculpin are found in coastal streams from Bristol Bay south and in the Aleutians as far west as Kiska Island. An isolated population is located in the Kobuk River (McPhail and Lindsey 1970, Scott and Crossman 1973, Morrow 1980).

Habitat - Coastrange sculpin occupy swift, gravel-bottomed riffle areas in streams and rivers, brackish water in estuaries, and along quiet lake shores (McPhail and Lindsey 1970, Scott and Crossman 1973, Ikusemiju 1975).

Spawning

Location - Spawning occurs in the lower reaches of streams and in estuaries (Ringstad 1974). McLarney (1968) found coastrange sculpin eggs above the intertidal zone of steep streams.

Nests - Eggs are deposited on the underside of rocks,

logs, or cutbanks (Ringstad 1974, Morrow 1980) and guarded by the males (McPhail and Lindsey 1970, Scott and Crossman 1973).

Season - In Washington, coastrange sculpin spawn between February and mid April (Ikusemiju 1975). In Canada spawning occurs in May and June (McPhail and Lindsey 1970).

Sexual Dimorphism - Spawning males have a broad orange stripe on the edge of the first dorsal fin, and a genital papilla which is longer than in females (McPhail and Lindsey 1970).

Age at Maturity - Patten (1971) reported that coastrange sculpin spawn at age 2.

Fecundity - Fecundity ranges from 100 to 1,800 eggs (Patten 1971, Ikusemiju 1975).

Eggs

Description - Eggs are adhesive, approximately 1.5 mm in diameter, and orange (McPhail and Lindsey 1970, Scott and Crossman 1973).

Incubation Period - In the laboratory, eggs raised at 10-12°C eyed at 9-10 days and hatched 19-20 days after fertilization (Mason and Machidori 1976).

The Larval Period

Young coastrange sculpin are very similar to young

prickly sculpin, hatching at about 5 mm and swimming to the surface within a few hours. They remain pelagic for 32-35 days before adopting a benthic lifestyle. In 6-10 days after hatching, the larvae of both species are able to feed on microplankton (Mason and Machidori 1976). Prejuveniles of prickly sculpin and coastrange sculpin can be differentiated by the number of anal fin rays. Coastrange sculpin have 12-15 anal fin rays while the prickly sculpin have 15-19 anal fin rays (McPhail and Lindsey 1970, Stein 1972).

DISCUSSION

This discussion is divided into three sections. The first section describes the process for identifying a larval fish using this thesis as a guide. This work will aid the fishery biologist until a larval fish key is available. The second describes sampling for larval fish. The last section discusses techniques for describing and illustrating larval fish.

Guidelines for Identifying an Unknown Larval Fish

It is not within the scope of this thesis to develop a key of larval fish. The descriptions provided and the following general guidelines, however, should help to identify an unknown larval fish collected from Alaskan freshwaters.

- 1) Note type of habitat and the area in Alaska where the fish was collected. Most Alaskan freshwater fishes spawn in swift, gravel-bottomed streams or lake shores. Fishes which spawn in densely vegetated ponds or lakes are the Alaska blackfish, the pond smelt, and the sticklebacks.

- 2) Determine the stage of development. If the yolk sac is present but there are no fin rays (or

actinotrichia), it is a protolarva. If a few rays are present in the dorsal and anal fins, it is a mesolarva. If all fin rays appear to be present but the larval finfold is still present, it is a metalarva. If the finfold is absorbed, it is a juvenile.

3) Count myomeres and fin rays in the median fins if visible.

4) Note the general outline of the fish's lateral view, especially noting the placement of the fins and the size and shape of the yolk sac if it is present.

With the general outline of the fish and any meristics available, look for possible families in which the larva might fit (Table 9). Armed with this general knowledge, turn to the descriptions for those families which fit the general description. For the species which are illustrated, perusal of the drawings should guide the observer toward the correct identification of the species. If the information suggests that the larva is a Pacific salmon, Trautman (1973) or Auer (1982d) should be consulted. For descriptions of trout, Martinez (1979) or Auer (1982d) can be consulted.

Proper identification of individual species is complicated by the fact that some of the species considered in

Table 9. General fish outline and physical characteristics for each freshwater fish family included in this study.


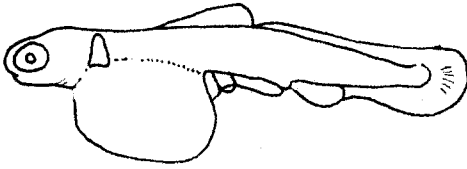



General Outline	Physical Characteristics
	<p>WHITEFISHES:</p> <ul style="list-style-type: none"> - newly hatched length < 14 mm - myomeres 50-63/ vertebrae 49-67 - preanal length 63-68% TL - predorsal length 31-49% TL - adipose fin and axillary process
	<p>CHARS:</p> <ul style="list-style-type: none"> - newly hatched length > 14 mm - myomeres 55-60/ vertebrae 61-71 - preanal length 60-62% TL - predorsal length 33-41% TL - adipose fin and axillary process - teeth well developed
	<p>GRAYLING:</p> <ul style="list-style-type: none"> - myomeres 54-58/ vertebrae 58-62 - preanal length 65-68% TL - predorsal length 18-34% TL - adipose fin and axillary process - enlarged dorsal fin with > 18 rays
	<p>SMELT:</p> <ul style="list-style-type: none"> - newly hatched length 4-5 mm - myomeres 55-70/vertebrae 58-70 - preanal length 65-75% TL - adipose fin but no axillary process
	<p>MUDMINNOW:</p> <ul style="list-style-type: none"> - newly hatched length 6 mm - myomeres ? /vertebrae 40-42 - preanal length ? - anterior position of dorsal and anal fin - rounded caudal fin

Table 9. (Continued)

General Outline	Physical Characteristics
	MINNOW: <ul style="list-style-type: none"> - newly hatched length 6 mm - myomeres 39-45 /vertebrae 39-44 - preanal length 56-69% TL - caudal fin moderately forked
	SUCKER: <ul style="list-style-type: none"> - newly hatched length 7-8 mm - myomeres 31-48 /vertebrae 45-47 - preanal length 62-77% TL - predorsal length 37-48% TL - no adipose fin
	TROUT-PERCH: <ul style="list-style-type: none"> - newly hatched length 6 mm - myomeres 32-34 /vertebrae 33-36 - preanal 44-52% TL - dorsal fin has 2 spines - anal fin has single spine
	BURBOT: <ul style="list-style-type: none"> - newly hatched length 3-4 mm - myomeres 55-65 /vertebrae 62-67 - preanal length 39-50% TL - pelvic fins under head - 2 dorsal fins with 2nd having 60-80 rays
	STICKLEBACKS: <ul style="list-style-type: none"> - newly hatched length 5-6 mm - myomeres 30 /vertebrae 30-35 - preanal length 51-58% TL - pelvic fins just behind head - several spines in front of dorsal fin
	SCULPINS: <ul style="list-style-type: none"> - newly hatched length 5-6 mm - myomeres 28-41 /vertebrae 31-38 - preanal length 41-50% TL - pelvic fins under head - two dorsal fins with 1st having 7-10 spines

this thesis show variability in meristic counts. Meristic variation can be caused by several environmental factors. Larvae reared in temperatures other than normal, for example, may have more vertebrae than larvae raised at normal temperatures. This is the case with the three-spined stickleback (Gasterosteus aculeatus). When reared at normal temperatures, these sticklebacks have 31 to 33 vertebrae. If reared at temperatures cooler or warmer than normal, however, an increase in the number of vertebrae occurs (Blaxter 1969). At higher temperatures, fewer pyloric caeca are produced (Savvaitova 1980). Intensity and duration of light can also affect meristics. Sockeye salmon (Oncorhynchus nerka) had lower vertebrae counts when exposed to a long photoperiod during incubation (Blaxter 1969). Additionally, increased oxygen and carbon dioxide during incubation can decrease the number of vertebrae whereas increasing the salinity may increase certain meristic characters. Finally, the number of gill rakers depends on the local abundance and size of the food items. (Blaxter 1969, Savvaitova 1980). Clearly, identification of a species cannot be determined solely by meristic characters.

Of the species considered in this thesis, the whitefishes exhibit the most variation in meristics. This is largely due to the highly varied habitat. Whitefishes are a very plastic species capable of adapting to different

types of habitat.

On a similar note, pigmentation can also show variability within a single species as a result of environmental factors (Moyle and Cech 1982, Snyder 1983). Fishes have the ability to concentrate or disperse pigment within each cell, for example, in avoidance of predation. Potentially, during specimen collection, the melanophores could assume a stellate pattern and thus, the specimens described in this thesis could possibly show a bias toward stellate rather than contracted melanophores.

As a result of the variation in meristics and pigmentation patterns due to environmental variability, it is not sufficient to rely on one characteristic alone to identify an unknown specimen. The only reliable method is to use multiple descriptors. Morphometric measurements and physical descriptions of the structural form, in concert with meristic counts and pigmentation patterns, will aide in identification. If this is coupled with knowledge of the habitat and season, it should be possible to limit the number of possible choices to at most two or three species. The likely groups where the observer will have difficulty are for the following:

Alaska blackfish - slimy sculpin: The slimy sculpin can be differentiated by its pectoral fin which is larger than that of the blackfish. The blackfish has very

distinctive dark black patches in the earliest phases of development.

Least cisco - sheefish - pond smelt: All of these fishes have a protruding lower jaw. Whitefish, however, have an axillary process; pond smelt do not. In the juvenile fishes, an axillary process should be visible. In the early larval stages, meristic and morphometric data (see text) are necessary for proper identification.

Whitefish: Differentiating among whitefish is more difficult. Morphometric measurements (see text) are necessary. Parr marks, if found, can help with identification. Only the pygmy whitefish and the round whitefish (and possibly humpback whitefish) have parr marks.

Sampling for Larval Fish

Larval fish samples for study and illustration can be collected either from hatchery- or laboratory-reared stock or sampled in the wild. Both methods have advantages, and it is probably best to use a combination of the two methods for best results. The advantages of collecting samples from a laboratory or hatchery are that the fish's species and time of development are known. A disadvantage is that the condition of the larvae is unknown. A raised fish may

be underfed, resulting in specimens which are uncharacteristically slender. While it is often difficult to determine the species of a wild specimen and its time of development, the larvae are in better condition and, most importantly, are closer in form to the fish larvae a key user will be trying to identify. The best solution is to use both hatchery-reared and wild caught larvae when preparing a key. This is not easy. In all cases, the source of the specimen should be indicated in the key.

Techniques for Describing and Illustrating Larval Fish

Although the drawings prepared for this thesis using camera lucida are a reflection of "what the observer saw," they are not always anatomically correct. For example, the connection of the pelvic fin to the body of the slimy sculpin larva is difficult or impossible to see under normal lighting conditions using a microscope. As a result, the drawings indicate a "best guess" at the nature of the fin connection. This connection could be determined using clearing and staining techniques, but that process is labor intensive and time consuming. The added work in my opinion, is not justified given the primary use of the drawings for identification of unknown species collected in Alaskan freshwaters, where differentiation of the freshwater sculpins is relatively straight-forward and does not have to rely on noting small details like fin connections. In other

parts of the North America, this information might be necessary. Even in those cases, however, the fin connection could not be seen by an observer, and the identification would probably have to be made on the visible characteristics alone. For completeness, however, such anatomical detail would be nice to include on the drawings.

The number of drawings of each species of fish included in this thesis may have been excessive. For example, the development of the slimy sculpin is rapid, with attainment of the juvenile period occurring in three weeks or less from hatching. The result is that changes between stages are often subtle and not sufficient to warrant a separate drawing. Realistically, it is best to limit the number of drawings to those necessary to illustrate significant physical differences between larval stages.

The work that went into this thesis illustrates the fact that the camera lucida is superior to photographs. However, there is greater detail in the illustrations than is necessary for larval fish identification. The drawings are 'artistic' and pleasing to look at, but the effort necessary to achieve this quality was time consuming. An average drawing took 16-24 hours to produce. Simplified drawings could be used which would still accomplish their intended purpose but reduce the work necessary to produce a key.

RECOMMENDATIONS

For 10 of the 23 species (Table 1) covered in this thesis there is sufficient information for a larval fish key. For the other 13 species, however, data are limited. Development of a comprehensive larval key will require additional study. For those 13 species with limited data, the following specific data are required:

- 1) Illustrations, morphometric data, meristics, and physical descriptions are lacking for least cisco, Bering cisco, pygmy whitefish, broad whitefish, and coastrange sculpin. For these species, hatchery-reared or wild-caught larvae need to be obtained for each early life stage to obtain the needed data.
- 2) Descriptions of the larval stages of the Arctic cisco are nonexistent so I substituted data on the Irish pollan, a conspecific. These two vary greatly in behavioral differences and environmental discrepancies are probable. Larvae of the Arctic cisco must be collected and studied to eliminate possible discrepancies.
- 3) Data on the metalarval stage and the juvenile period are needed for ninespine stickleback.

- 4) Morphometrics for all stages of prickly sculpin are needed.
- 5) Additional data should be collected on the morphometry and meristics of Alaska blackfish.
- 6) For the humpback whitefish complex, I used data for lake whitefish larvae collected in the Great Lakes area. As with the Arctic cisco, larvae from known humpback whitefish should be collected and studied to avoid possible discrepancies between the two species.
- 7) Local data on burbot should be collected. Basic questions such as where burbot spawn in Alaska need to be answered.

Based on Morrow (1980), there are approximately 40 species of freshwater fishes in Alaska. Only 23 species were covered in this thesis, and the remaining 17 would have to be treated in a comprehensive key. These fishes include lampreys, the northern pike, the three-spine stickleback and several anadromous species including sturgeon, the trouts, the Pacific salmon, the longfin smelt, and the eulachon. Except for the sturgeons and smelts, there is probably sufficient data for a larval key.

Actually, two keys are required. A single key is

inadequate because of the major changes in morphology which occur during larval development. One key is needed for the protolarval and mesolarval stages when the yolk-sac is present or recently absorbed but prior to fin-ray differentiation. A second is required for the metalarval and juvenile stages where the adult complement of principal rays become evident. In general, the second key will be easier to produce than the first because the information available on adult meristics (such as vertebrae and ray count) are apparent in the metalarval and juvenile stages.

In addition to the fact that existing data are scarce for the earliest stages, the first key will require more work than the second because of the detail required. Differences between species are less pronounced during the protolarval and mesolarval stages than in the metalarval and juvenile stages, therefore, the first key must contain specific morphometric data, meristics, and physical descriptions. We can not depend on adult meristics with this key.

The keys should include morphometric data because some species can not be differentiated without them. Snyder (1979) recommends taking 20 length, 6 depth, and 6 width measurements for closely-related species; this requires intensive work and is extremely time consuming. Except for some of the whitefish species where these data may be useful, an abbreviated set of measurements as listed in Table 2

should be sufficient and requires less work.

Little specific data on larval descriptions have come from studies of Alaskan specimens with the exception of Alaska blackfish and the 6 species which I studied and illustrated. We need to ascertain that the data collected are applicable to local Alaskan fishes. This can only be done by comparing local specimens to those of other regions.

Finally, the key needs to be useful to field technicians unfamiliar with the complex nomenclature of early development. A comprehensive glossary of essential terms should be provided along with simple illustrations depicting specific anatomical features critical for identification purposes. Illustrations like Figure 1 and more detailed illustrations such as a detail of branchiostegal rays will go a long way towards making a more useable key.

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